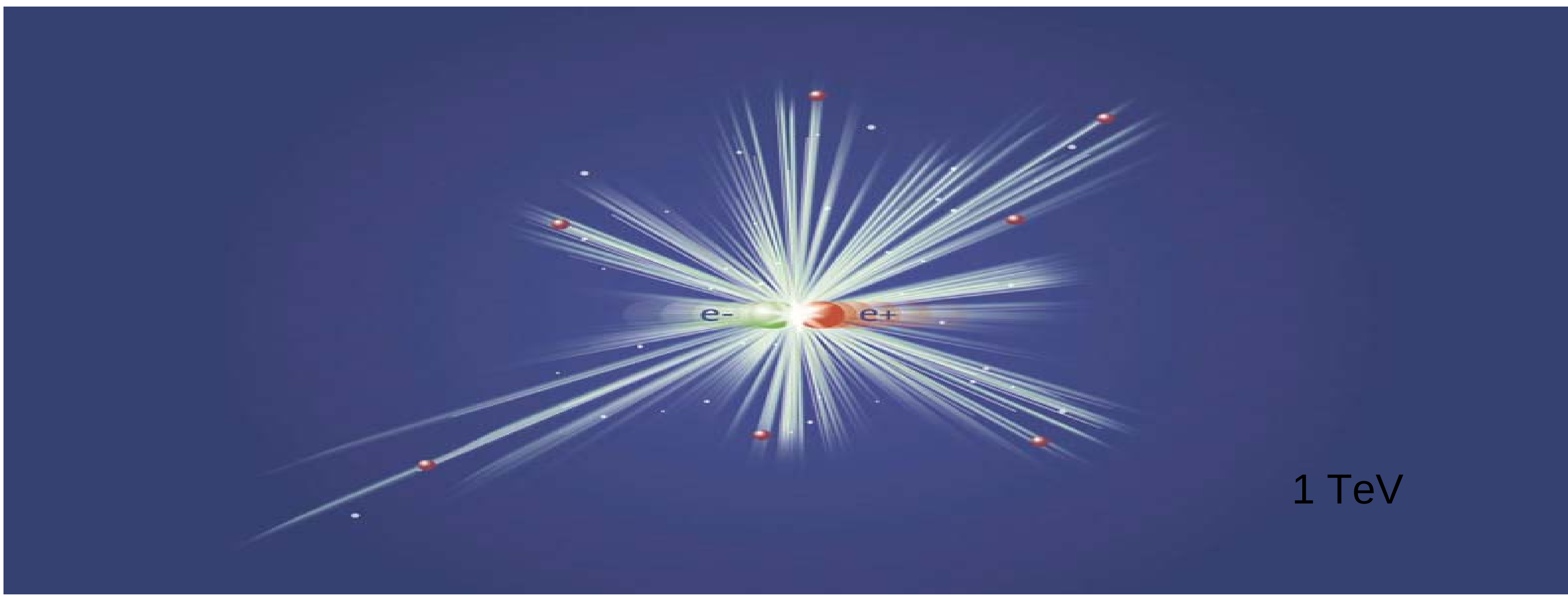
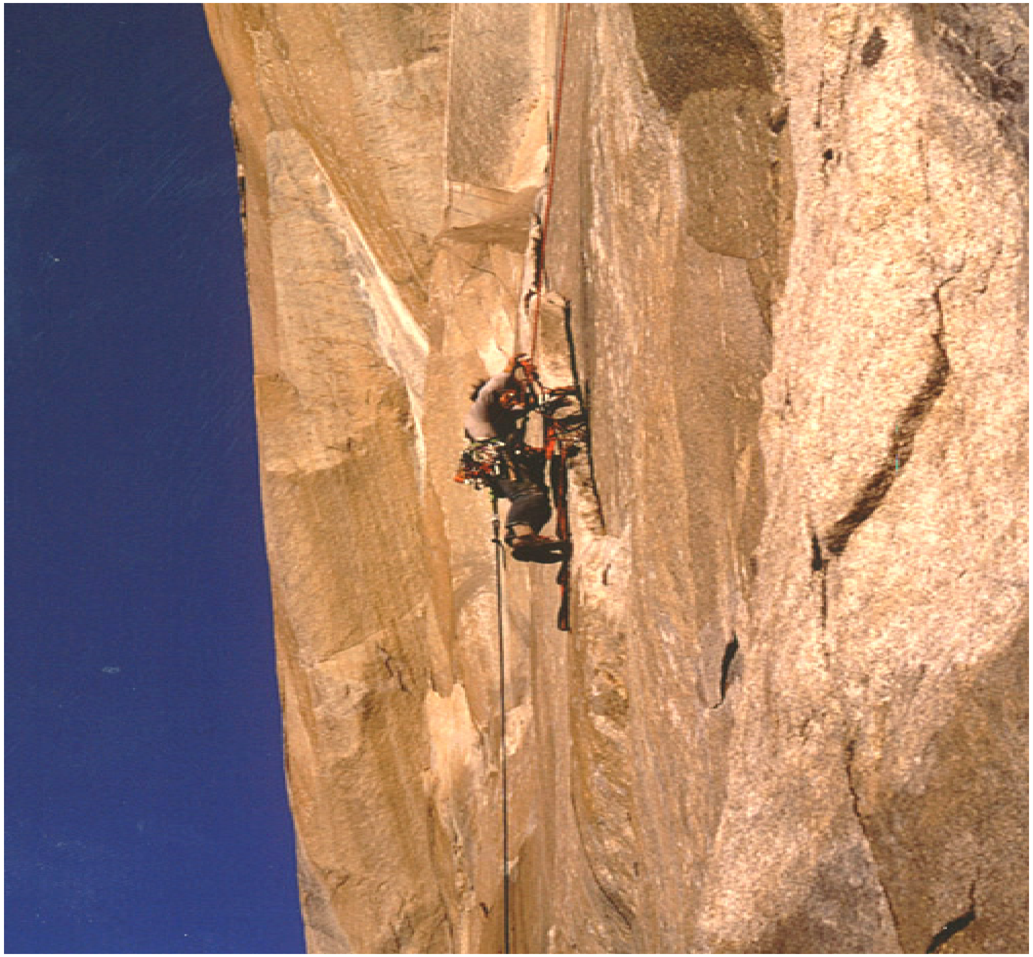
International Linear Collider

Shekhar Mishra

Fermilab



Particle Physics Progress
20th Century



Physicists want a grand View of the Universe

Are We Near the Top?

String theorist Burt Ovrut hanging from a rope

Quantum Universe:
THE QUESTIONS

1. Are there undiscovered principles of nature :
   New symmetries, new physical laws?

2. How can we solve the mystery of dark energy?

3. Are there extra dimensions of space?

4. Do all the forces become one?

5. Why are there so many kinds of particles?

6. What is dark matter?
   How can we make it in the laboratory?

7. What are neutrinos telling us?

8. How did the universe come to be?

9. What happened to the antimatter?

	Tevatron	LHC	Linear Collider	NuMI / MINOS	ν Superbeams	BaBar	BTeV	JDEM	RHIC	Proton Decay
Undiscovered Principles? 1	X	X	X			X	X			
Dark Energy? 2		X	X					X		
Extra Dimensions? 3		X	X							
Unified Forces? 4			X							X
Why So Many Particles? 5	X					X	X			
Dark Matter? 6			X					X		
Neutrinos? 7				X	X					
Origin of Universe? 8		X							X	
Antimatter? 9					X	X	X			

Each one of these topics is at least a talk by itself.

Key Points for Why We Need an ILC

The precision of the ILC data will provide clarity of understanding of the physics at the TeV scale in a model independent way (J.H.)

- New physics is expected at the TeV scale
- LHC is a great discovery machine and more
- LHC will not make precision tests of Higgs
- ILC has well defined initial energy which can be varied
- ILC will have high polarization of e- and perhaps e+

- Discoveries at LHC lead to questions such as:
  – Is it really the standard model Higgs? Measure couplings
  – Is that super-symmetry? Measure spin and quantum nos.
  – Is that neutralino “dark matter”? Measure mass to 1%
  – How many extra dimensions are there? LHC+ILC best

A Successful Pattern of Hadron Colliders Complementing e+e- Colliders

- UA1 and UA2 discovered the W and Z bosons at a hadron collider
- LEP approved before Z discovered
- Polarized e-p experiment at SLAC pinned down ratio of W/Z masses
- LEP searches and precision measurements eliminated many models eg. limits on lepto-quarks, 4th generation quarks and leptons
- Minimal Susy still consistent with all the data, hence it is still the most possible extension of the standard model
- The precision electroweak data from LEP and Tevatron is self consistent. That is the indirect and direct constraints on the observables are consistent at radiative correction level
- The machine energy can be controlled to scan across resonances unlike a hadron machine with structure function uncertainties-line shape
- We now believe with “great confidence” that a Higgs exists or something that performs that function at the TeV scale
- Running coupling constants support SUSY and Unification
- e+ e- precision tool provides window for the next scale of new physics

New York Times and OSTP Quotes

- “Physicists think they have a pretty good story to tell these days, about the big bang, black holes, dark energy, extra dimensions and multiple universes. In the 30 years I have been following this stuff, it has never been wilder. But the real best seller here is wonder….There’s a whole universe out there, and nobody knows how and why.”

  Dennis Overbye, New York Times, July 27, 2004

- “Opportunities have emerged for discovery about the fundamental nature of the universe that we never expected,” Presidential Science Advisor John Marburger said recently. “Technology places these discoveries within our reach, but we need to focus efforts across widely separated disciplines to realize the new opportunities.”

Higgs at ILC

- Important goal of the ILC physics.
- Establish the mass generation mechanism of elementary particles => coupling determination
- Determine the dynamics of electroweak symmetry breaking. “What is the Higgs particle?” One mode of the superstring, or a composite state of a new strong interaction?
- Although the present EW analysis favors a light Higgs boson (<250 GeV) within the SM, the Higgs sector is largely unknown.
- There are new ideas on the Higgs mechanism

Okada Summary Talk Victoria

ITRP (Wise Cold People)

(International Technology Recommendation Panel)

"This recommendation is made with the understanding that we are recommending a technology, not a design."

Super conducting RF is accelerating technology choice (all aboard!)

Linear Collider News (HEPAP Summary)

Director of GDE (Global Design Effort) - Barry Barrish

DOE LC budget: $23M in FY05 --> $25M in FY06 Request

NSF LC budget: $0.3M in FY05 and a similar number for FY06

Ray Orbach's statements at HEPAP meeting.

* LC in US (Fermilab) - We should go for it.
* The community should work hard on reducing the cost.

  US cost estimate was $10-12B and this is too expensive.

  $6B is feasible (he knows how to do it) assuming that US pays $3B.

Private communication Y. K. Kim, member HEPAP sub-panel

International Performance Specification

- Initial maximum energy of **500 GeV**, operable over the range 200-500 GeV for physics running.
- Equivalent (scaled by 500 GeV/$\sqrt{s}$) integrated luminosity for the first four years after commissioning of **500 fb^{-1}**.
- Ability to perform energy scans with minimal changeover times.
- Beam energy stability and precision of 0.1%.
- Capability of **80%** electron beam **polarization** over the range 200-500 GeV.
- **Two interaction regions**, at least one of which allows for a crossing angle enabling $\gamma\gamma$ collisions.
- Ability to operate at **90 GeV** for calibration running.
- Machine upgradeable to approximately **1 TeV**.

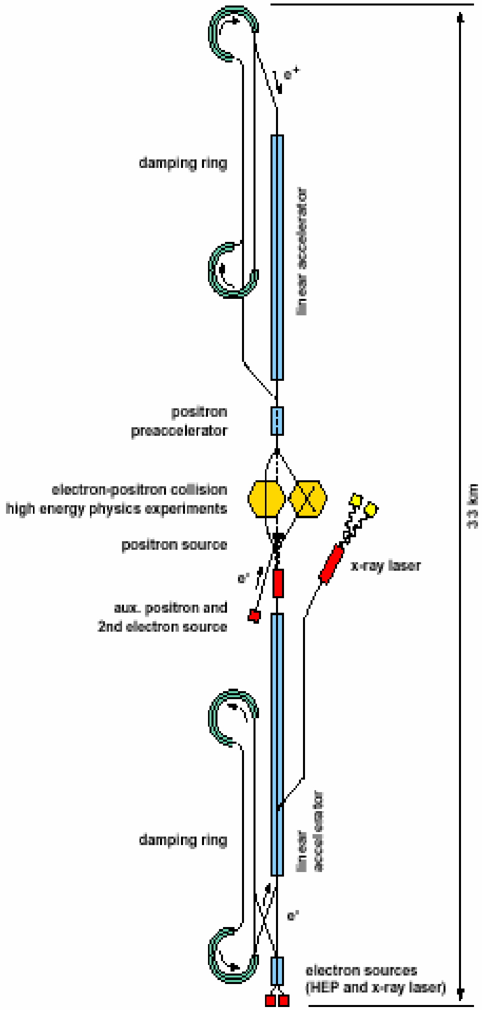
International Linear Collider: Physical Layouts and Configurations

Two concepts developed to date:

- TESLA TDR
- USLCSG Study

Possible considerations:

- Energy/luminosity tradeoffs at "500" GeV
- Undulator vs. conventional e^+ source
- Upgrade energy
- Head on vs. crossing angle IR
- Upgrade injector requirements
- One vs two tunnels



TESLA TDR

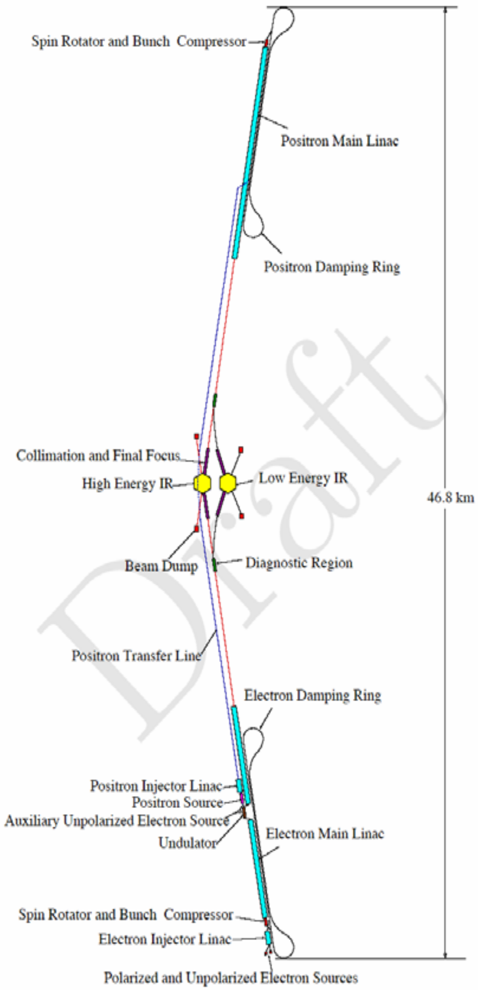


Figure 3.5.1.1: Overall Machine Layout, 500 GeV c.m.

USLCSG Study

ILC Performance Parameters

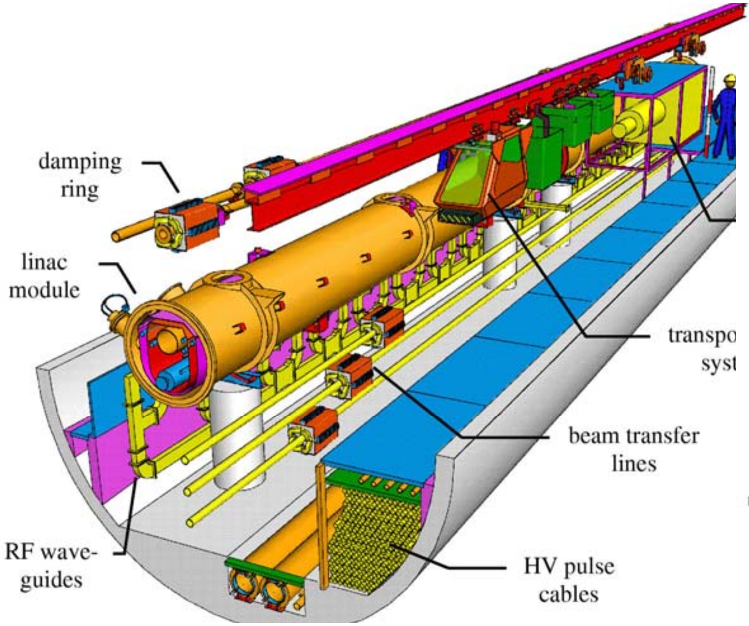
	TESLA/TRC		U.S. Study			
Center of Mass Energy	500	800	500	1000		GeV
Design Luminosity	34	58	26	38		$10^{33}cm^{-2}sec^{-1}$
Linac rf frequency	1.3		1.3			GHz
Unloaded/loaded gradient	24/24	35/35	28/28	35/35		MV/m
Pulse repetition rate	5	4	5			Hz
Bunches/pulse	2820	4886	2820			
Bunch separation	337	176	337			nsec
Particles/bunch	2	1.4	2			$x10^{10}$
Bunch train length	950	860	950			μsec
Beam power	11	18	11	23		MW/beam
$\gamma\varepsilon_H/\gamma\varepsilon_V$ at IP	10/.03	8/.015	9.6/.04			mm-mrad
σ_x/σ_y at IP (before pinch)	554/5	392/3	543/6	489/4		nm
Site AC power	140	200	180	356		MW
Site length	33		46			km
Tunnel configuration	Single		Double			

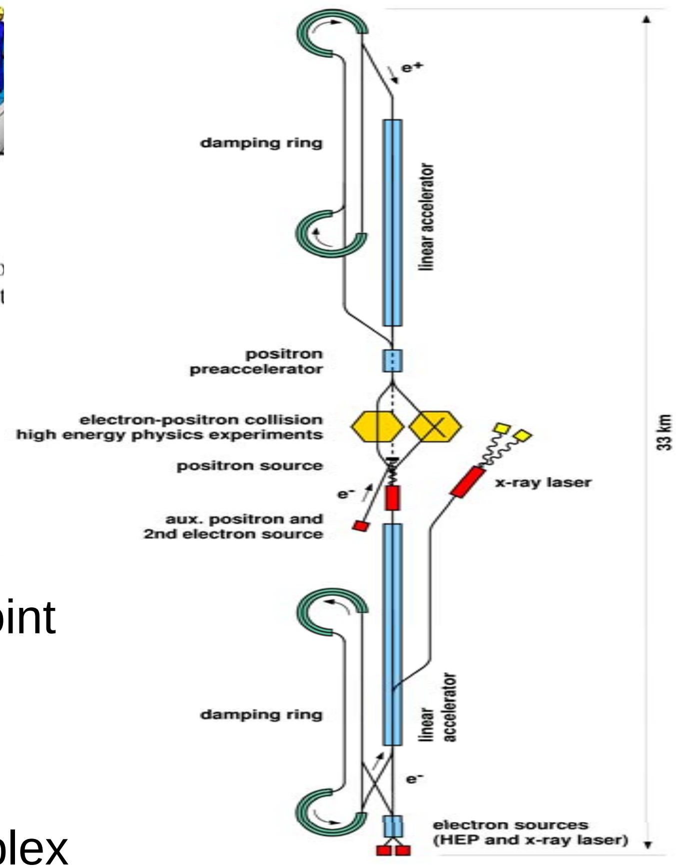
ILC has started discussion on coming up with a new parameter set and CRD.

ILC: Design Needed

Need 2000 cryomodules for 500 GeV

4000 for a 1TeV machine (12m each)





Tesla Design is a Good Starting Point

R&D Needed to secure 35 MV/m accelerating gradient

cavity processing procedures complex

Niobium surface

ILC Requirements and Challenges

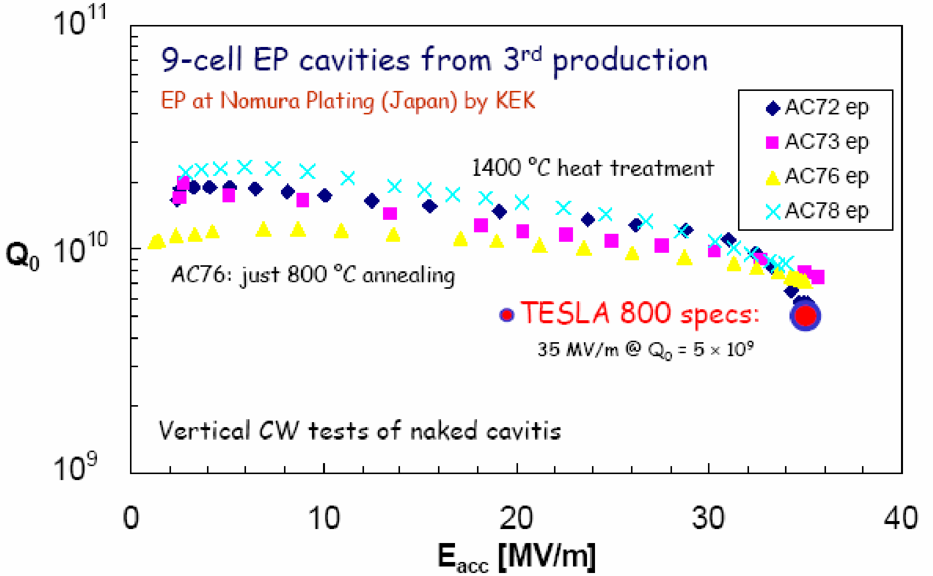
Energy: 500 GeV, upgradeable to 1000 GeV

- RF Structures
  - The accelerating structures must support the desired gradient in an operational setting and there must be a cost effective means of fabrication.
    - 24-35 MV/m × 20 km
    - ~21,000 accelerating cavities/500 GeV
- RF power generation and delivery
  - The rf generation and distribution system must be capable of delivering the power required to sustain the design gradient
    - 10 MW × 5 Hz × 1.5 msec
    - ~600 klystrons and modulators/500 GeV
  - The rf distribution system is relatively simple, with each klystron powering 24-36 cavities.

⇒ Demonstration projects: TTF-I and II(DESY); SMTF(USA-FNAL), STF at KEK in conceptualization phase

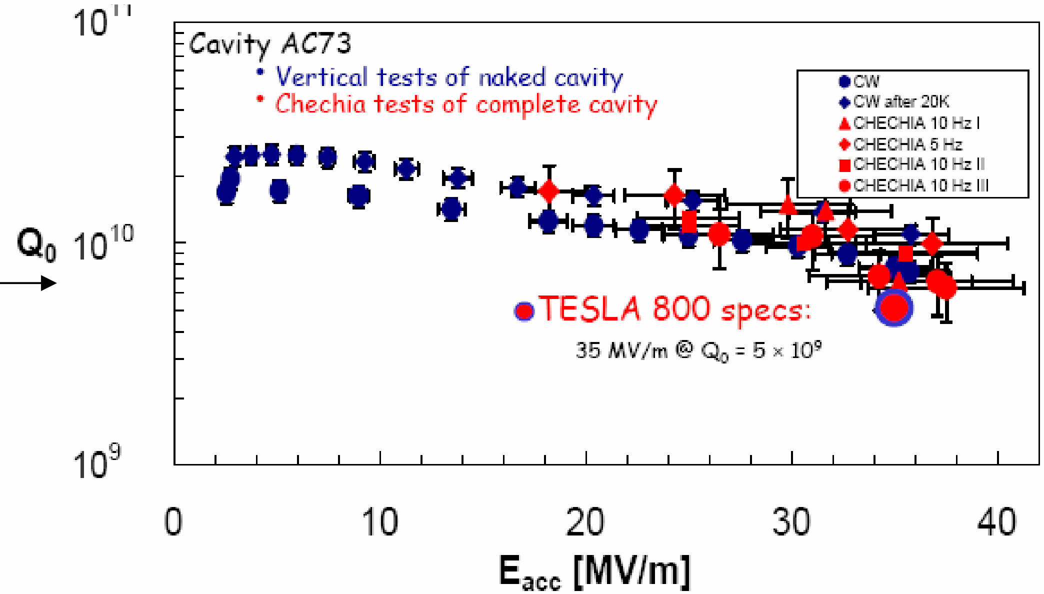
ILC Technology Status

Accelerating Structures



Vertical (low power test)

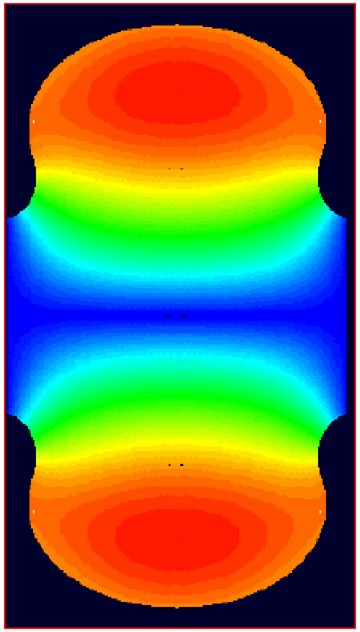
Comparison of low and high power tests (AC73)



High Gradient Cavity R&D

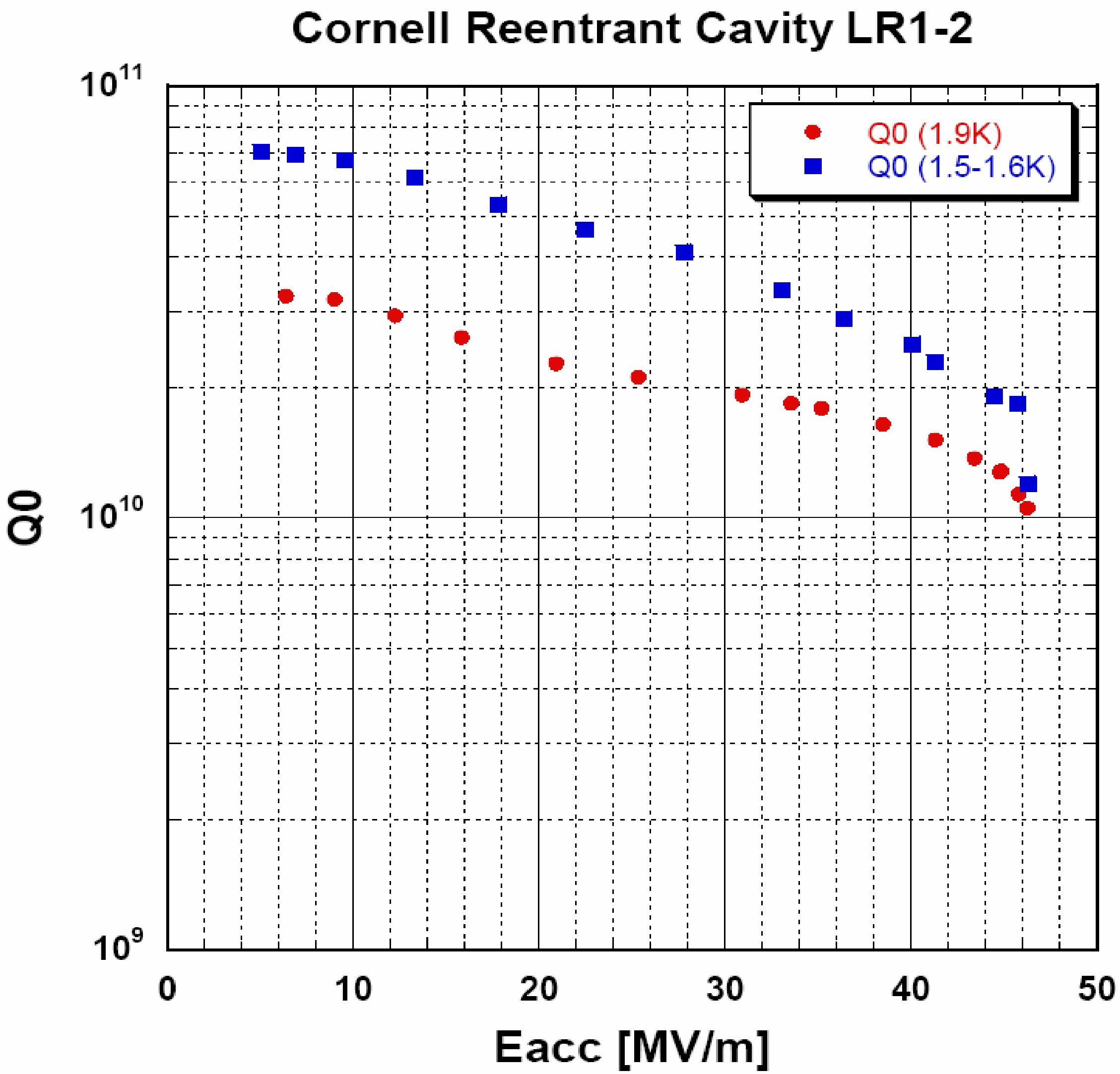
Re-entrant

RE shape



Cornell University

KEK will push this R&D



Site power: 140 MW (500 GeV baseline)

Main Linacs
97MW

Sub-Systems
43MW

RF:
76MW

78%

Cryogenics:
21MW

Injectors

Damping rings

BDS

Auxiliaries

65%

60%

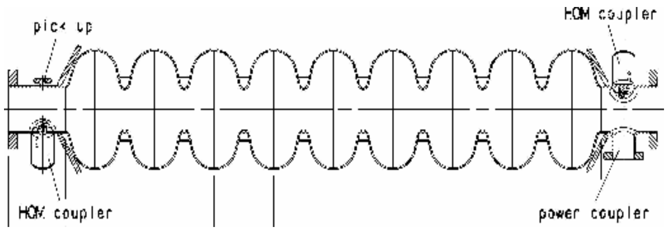
Beam
22.6MW

Optimized cavity design and rules

Major contributions from: CERN, Cornell, DESY, CEA-Saclay

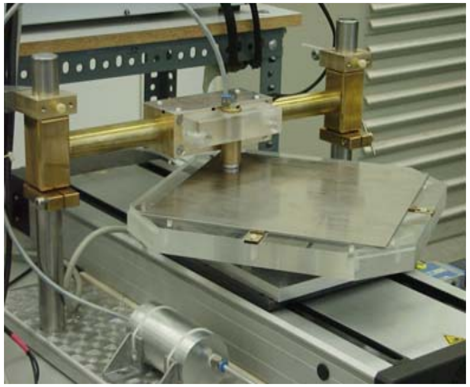
No US Industry can do this processing only Europe and KEK

- **9-cell, 1.3 GHz**



TESLA cavity parameters

R/Q	1036	Ω
E_{peak}/E_{acc}	2.	
B_{peak}/E_{acc}	4.26	mT/(MV/m)
$\Delta f/\Delta l$	315	kHz/mm
$K_{Lorentz}$	≈ -1	$Hz/(MV/m)^2$



Eddy-current scanning system for niobium sheets

Cleanroom handling of niobium cavities

Preparation Sequence

- Niobium sheets (RRR=300) are scanned by eddy-currents to detect avoid foreign material inclusions like tantalum and iron
- Industrial production of full nine-cell cavities:
    - Deep-drawing of subunits (half-cells, etc.) from niobium sheets
    - Chemical preparation for welding, cleanroom preparation
    - Electron-beam welding according to detailed specification
- 800 °C high temperature heat treatment to stress anneal the Nb and to remove hydrogen from the Nb
- 1400 °C high temperature heat treatment with titanium getter layer to increase the thermal conductivity (RRR=500)
- Cleanroom handling:
    - Chemical etching to remove damage layer and titanium getter layer
    - High pressure water rinsing as final treatment to avoid particle contamination

String Assembly

The assembly of a string of 8 cavities into a string. Class 100 clean room

Facilities being setup at Fermilab as part of SMTF.

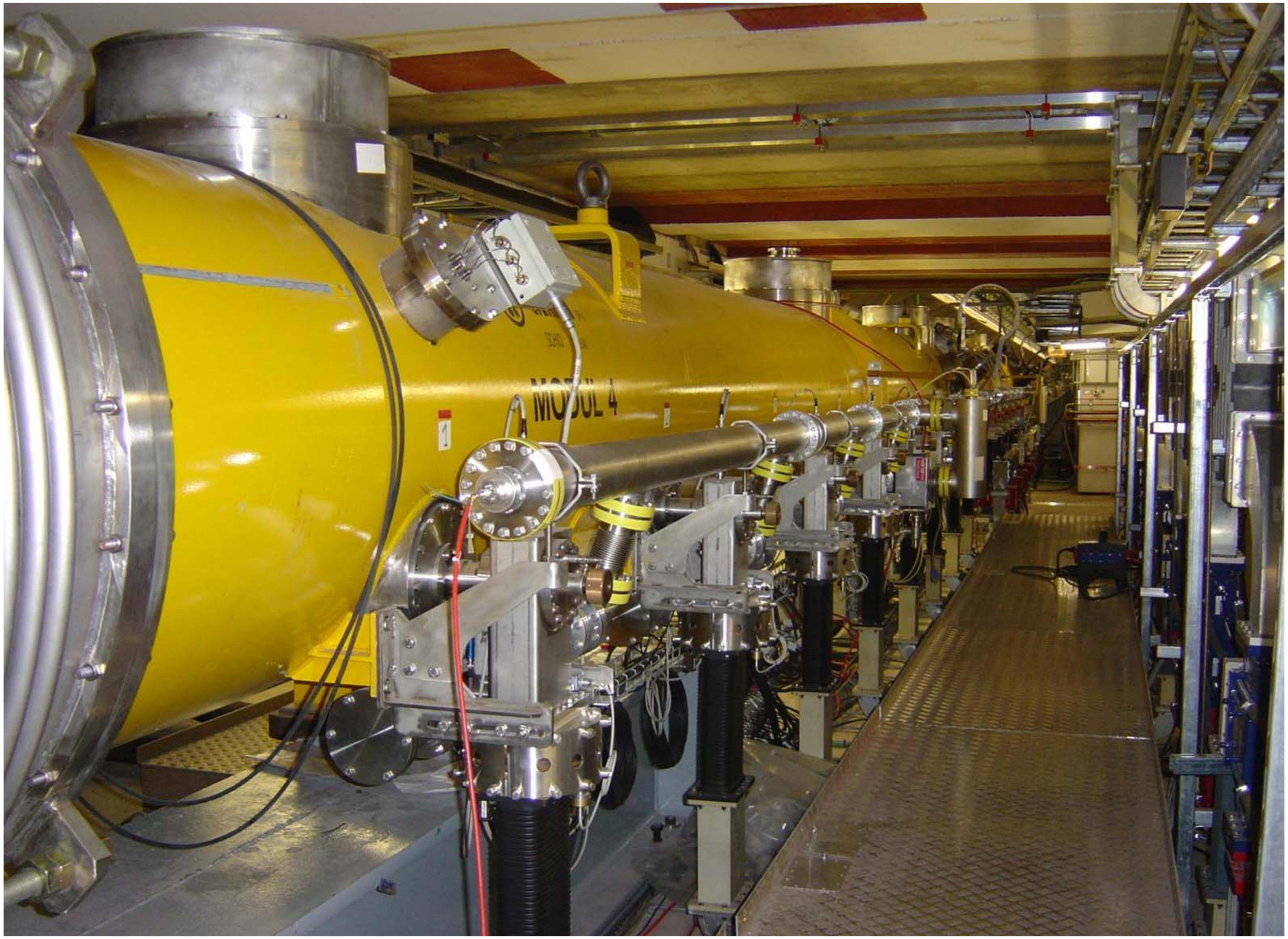
The inter-cavity connection is done in class 10 cleanroom

Module Assembly

The module assembly is well defined and about 10 modules have been made of several designs

ILC will need about 4000 modules.

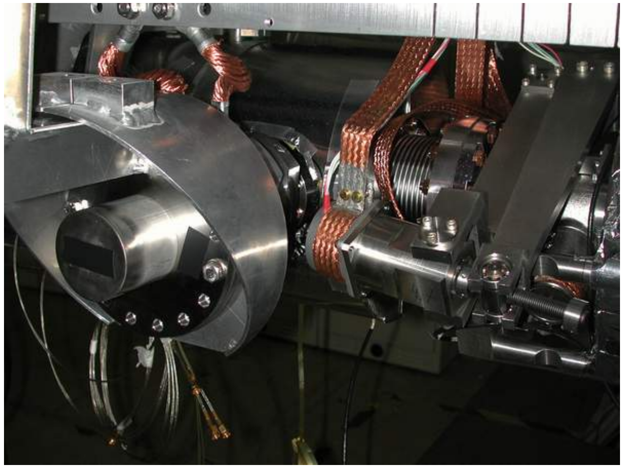
Cryomodules at DESY TTF

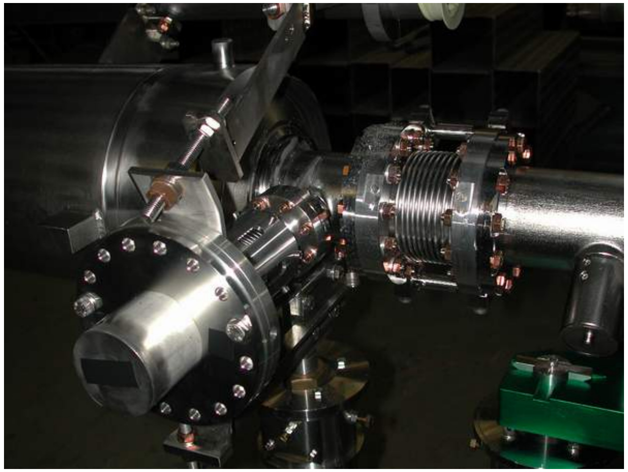


International Linear Collider
ILC America @ Fermilab

TESLA Tuners

TTF / X-FEL Tuner



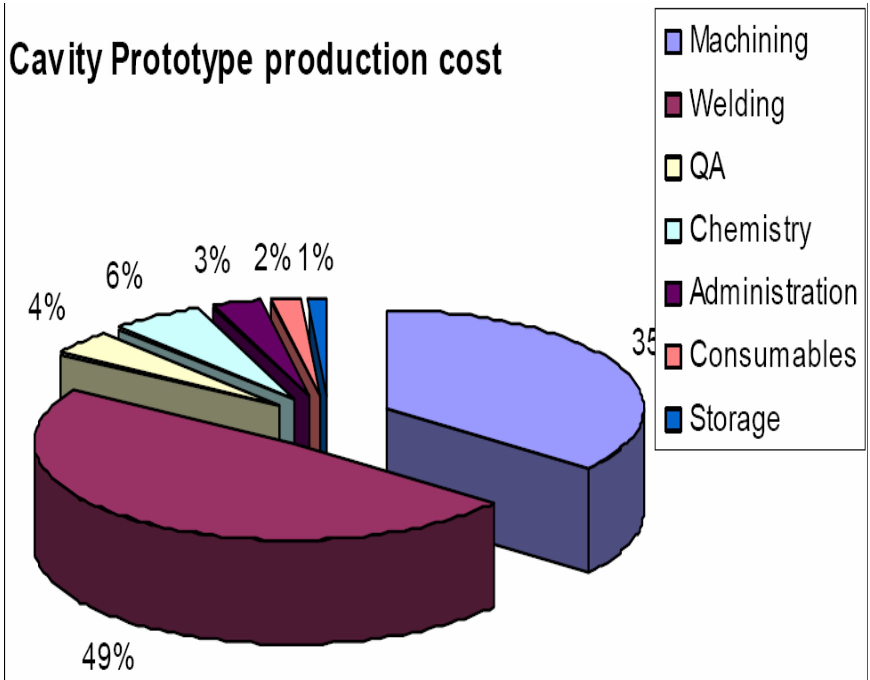


TESLA Blade-Tuner

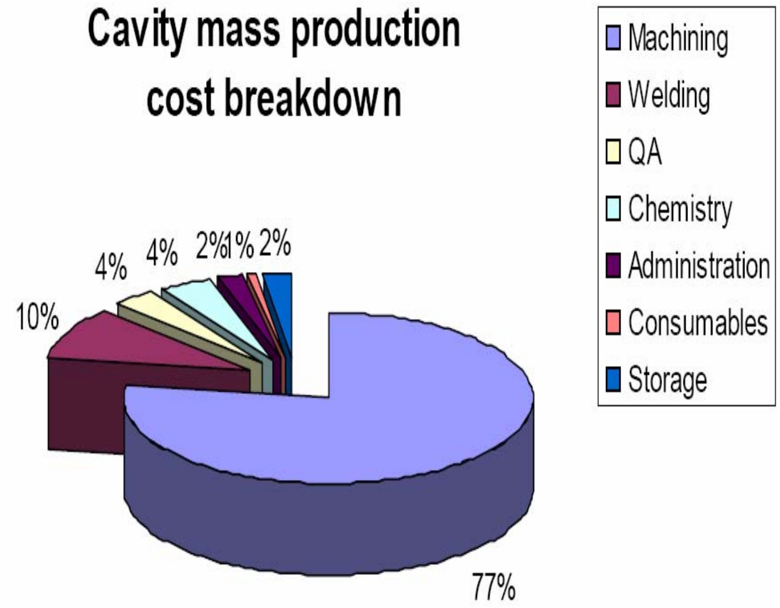
Successfully operated with superstructures

Piezo-tuner integration still pending

Cost and Design Optimization



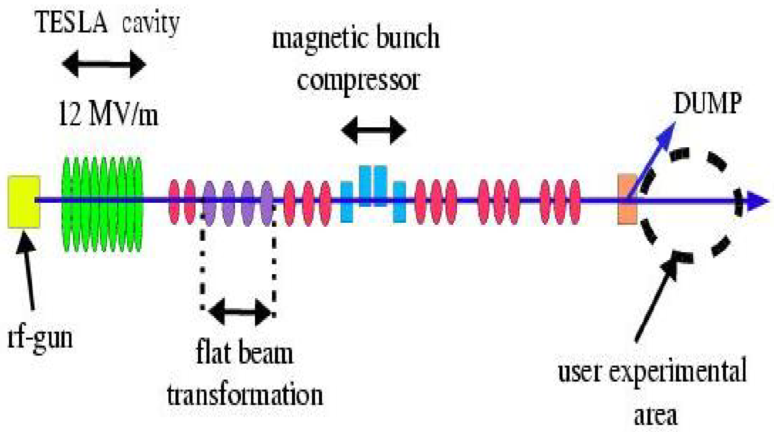
D. Proch



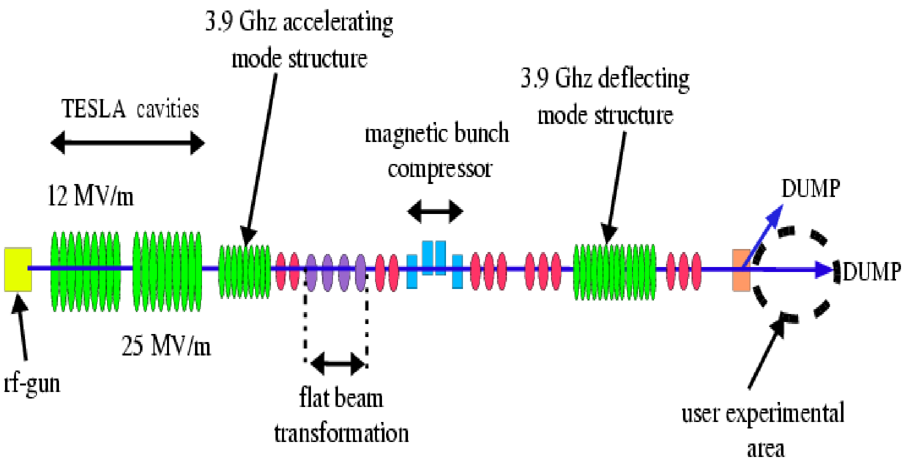
DESY is leading the effort in ILC/XFEL cost reduction.

Fermilab engineering will work with ILC collaborators in reducing the cost.

The Fermilab NICADD Photoinjector Laboratory (FNPL)



FNPL Upgrade



•2nd incarnation of the TTF Injector II, with extended diagnostics,
• One normal conducting rf gun, one superconducting booster cavity
• Beam energy up to 16 MeV, bunch charge up to 12 nC
• Normalized emittance 3-4 π mm mrad (with 1 nC)
• Beam physics studies with high brightness beams
• Experimental area for advanced accelerator concepts
• Education of students

ILC Technology Status

RF Sources

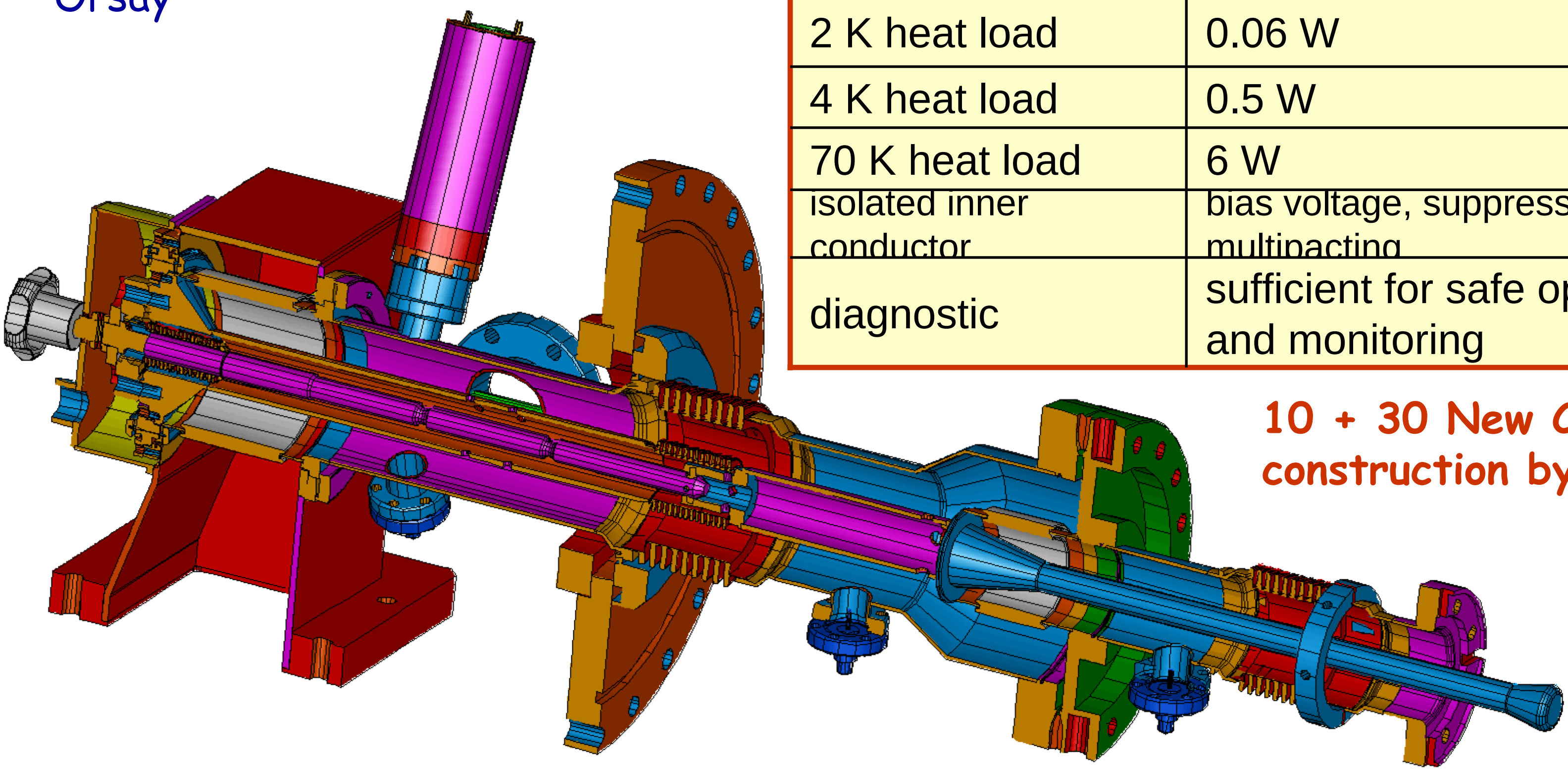
- Three Thales TH1801 Multi-beam klystrons fabricated and tested.
  - Efficiency = 65%
  - Pulse width = 1.5 msec
  - Peak power = 10 MW
  - Repetition rate = 5 Hz
  - Operational hours (at full spec) = 500 hours
  - Operational hours (<full spec) = 4500 hours

- Independent MBK R&D efforts now underway at CPI and Toshiba
- 10 Modulators have been built
  - 3 by Fermilab and 7 by industry
  - 7 modulators are in operation
  - Based on Fermilab design
  - 10 years operation experience

The TTF III Power Coupler

- TTF III Coupler has a robust and reliable design.
- Extensively power tested with significant margin
- New Coupler Test Stand at LAL, Orsay

frequency	1.3 GHz
operation	pulsed: 500 µsec rise time, 800 µsec flat top with beam
two windows, TiN coated	• safe operation • clean cavity assembly for high Eacc
2 K heat load	0.06 W
4 K heat load	0.5 W
70 K heat load	6 W
isolated inner conductor	bias voltage, suppressing multipacting
diagnostic	sufficient for safe operation and monitoring



10 + 30 New Couplers in construction by industry

ILC Technology Status

Examples of Outstanding Issues

- RF Structures and Source
  - Establish gradient goal
  - Develop capability for fabricating high gradient cavities
  - Coupler design
  - Controls/LLRF
  - Industrialization
- Particle Sources
  - Conventional e+
- Damping Rings
  - Length of the current design
  - Common tunnel
  - Commissioning
  - New design concepts to reduce circumference
- Emittance Preservation
  - Alignment of structures inside cryomodules
  - Instrumentation and feedback systems
- Maintaining Beams in Collision
  - Feedback
  - Head-on IR?
- Machine Protection
  - Collimation systems
- Civil
  - 1 tunnel vs. 2
  - Near surface vs. deep

Fermilab: Recent ILC Related News

- Fermilab has expressed publicly (ITRP):
  - In the event of the cold recommendation “Fermilab is ready to provide the leadership in forming a U.S. collaboration to develop SCRF high gradient technology in coordination with the international community.”
  - Fermilab is the site for the International Linear Collider

- On Aug. 20th 2004, the ITRP recommended the “Cold” Technology for the International Linear Collider.

- Fermilab will now follow through on this commitment

- Recent DOE FY06 budget and future projection and presentations to HEPAP suggests that Fermilab will probably be the only US site for particle physics accelerator in the future.

- The particle physics community around the world is coming to the conclusion that the best opportunity for building the ILC is near Fermilab.

What next for Fermilab?

- In FY 2009, at the end of Tevatron Run II, Fermilab will still be operating NuMI/MINOS for at least another year, and will participate in LHC and various particle astrophysics programs. The future of Fermilab past the end of the decade will be the subject of a continuing dialogue between the Administration, Congress, the laboratory, and the broader U.S. and international particle physics communities.

- We now look forward to working with Fermilab management to develop the strongest possible future for the laboratory as well as for the overall HEP program.

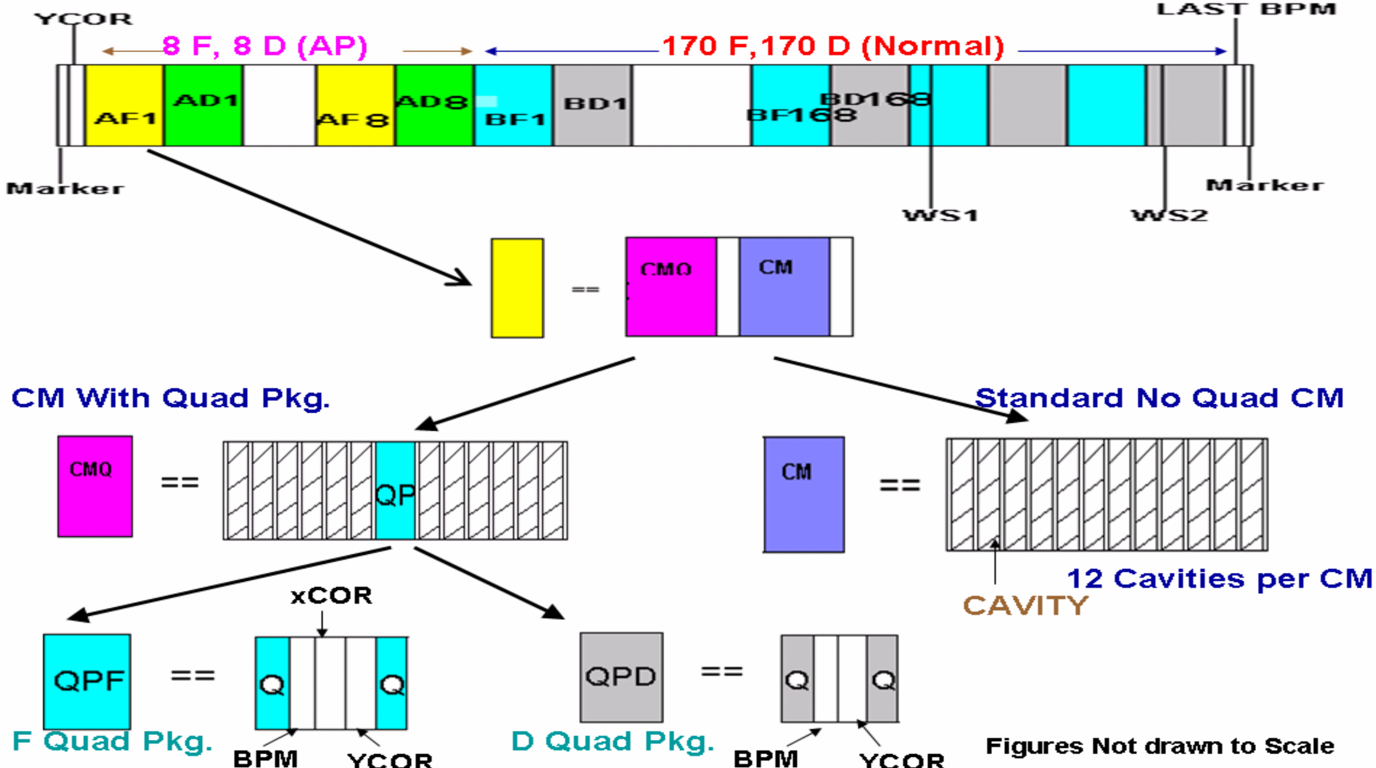
- The laboratory's Long Range Plan has laid out a broad and exciting program for the next decade, centered on the International Linear Collider, significant new initiatives in neutrino physics, the LHC physics center, and particle astrophysics and underground experiments.

- We are committed to maintaining Fermilab as one of the world leading scientific facilities.

Fermilab: ILC R&D

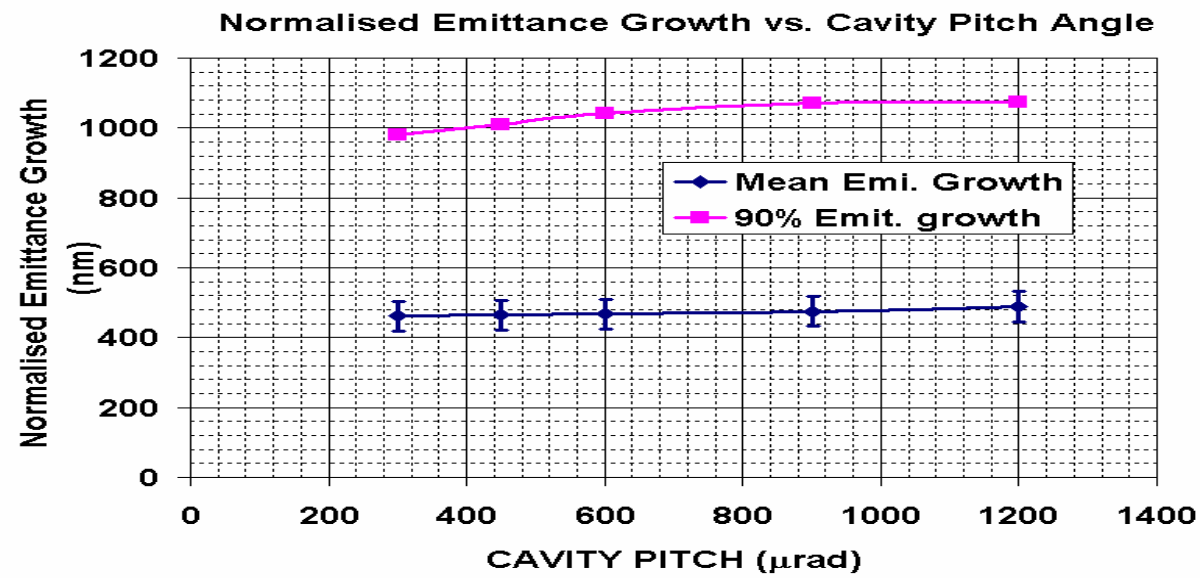
- ILC Accelerator Physics and Technology R&D
  - Accelerator Technology
    - SCRF Existing Infrastructure: FNPL, 3rd Harmonic Cavity
    - Main Linac (Fermilab will seek to take major responsibility)
    - SCRF: Cavity, HOM, Blade Tuner, Coupler, He and Cryo-vessel,cryo system and plant design
    - RF power for the Linac
    - Fast Kicker Development from Damping Ring
    - Source
  - Accelerator Physics
    - Linac Design, Emittance Preservation Simulation
    - Damping Ring Design, Instability calculations
    - Collimation and Machine detector interface
    - Electron Source
- Civil: Near Fermilab site, Tunnel, Vibration studies
- Detector R&D: SID, Silicon Detector and Readout, Muon, Fast Readout
- Collaboration & Outreach: Universities and ANL, National and International laboratories and Universities, Local public, State and Federal Government and international agencies.

MATLIAR SIMULATION: USCOLDLC MAIN LINAC (500 GeV CM)

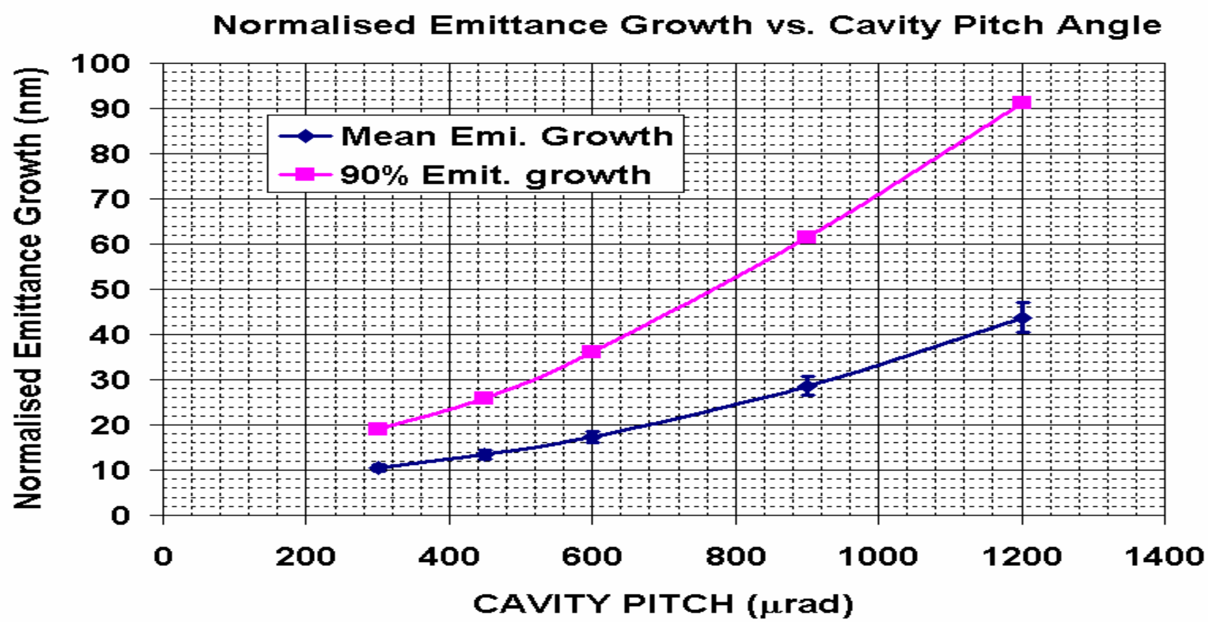


- US Cold LC Main Linac Design
  - Adapted from the TESLA TDR
  - Linac Cryogenic system is divided into Cryomodules(CM), with 12 structures / CM
  - Superconducting Quads in alternate cryostats, 356 Quads (178 F, 178 D)
  - Magnet Optics is a FODO lattice, with β phase advance of 60^0 in each plane
  - Initial 32 CM are provided with Autophased cavities for BNS damping
  - Each quad has a Cavity style BPM and a vertical corrector magnet; horizontally focusing quads also have a nearby horizontal corrector magnet.

EFFECT OF *STRUCTURE PITCH* VARIATION



FLAT



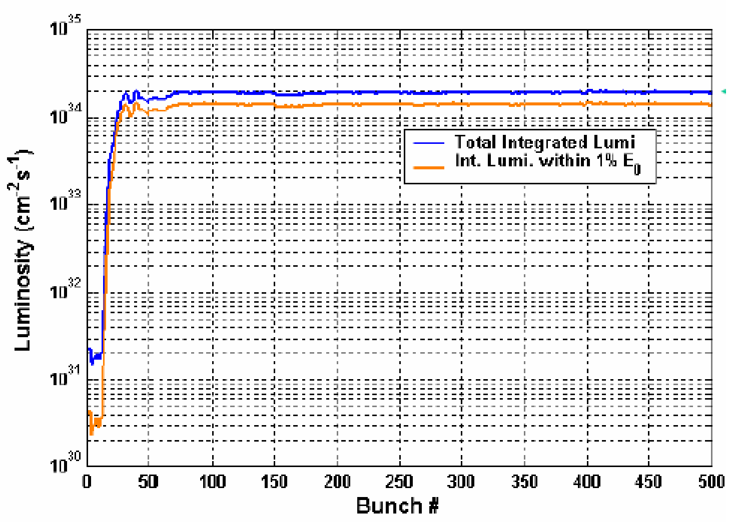
DFS

OLD WF USED

ILC Technology Status
Emittance Preservation

- Emittance growth budget from DR to IR is:
  - ×1.2 (horizontal), × 2.0 (vertical)

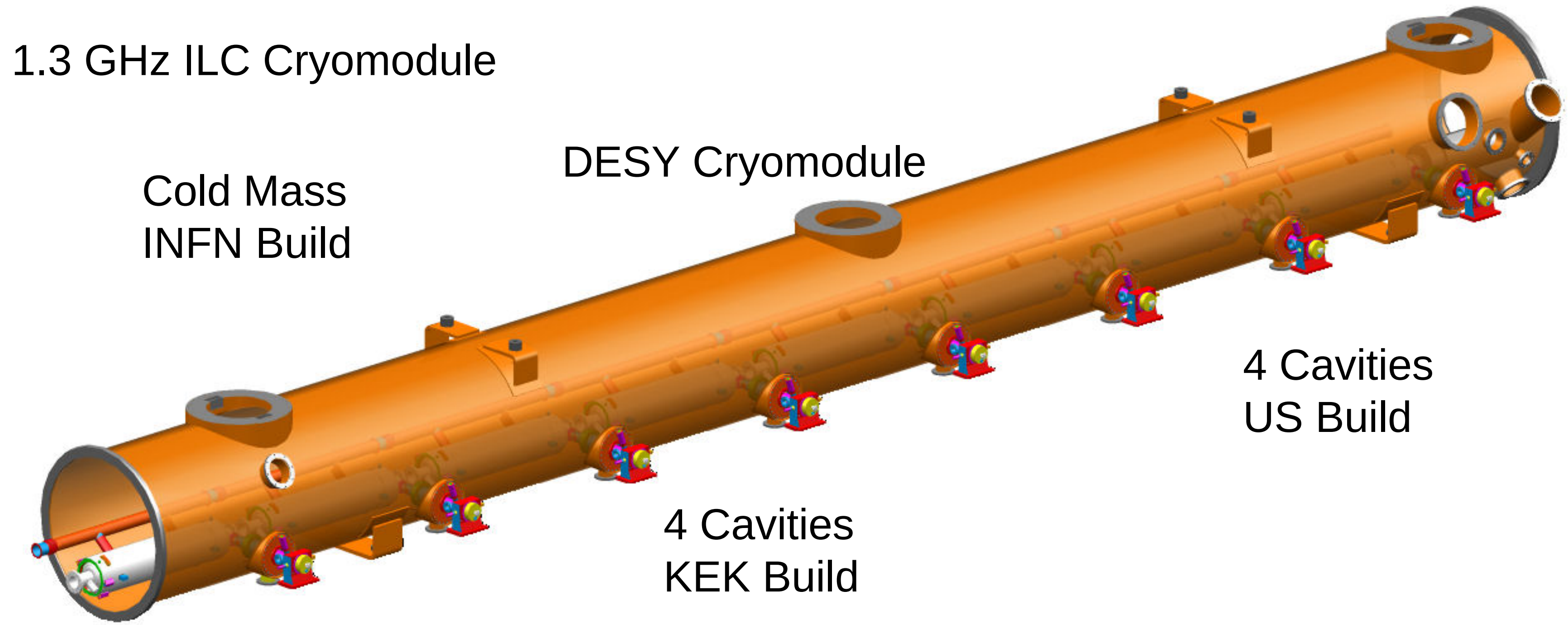
- Sources of emittance growth include:
  - Wakes
    - Single bunch controlled by BNS damping
    - Multibunch controlled by HOM dampers and tune spread
  - Alignment and jitter
    - Vertical dispersion × momentum spread = emittance growth
    - Controlled by alignment and correction algorithms (feedback)
    - Alignment tolerances ~300 mm, 300 mrad; BPM resolution ~10 mm



- Maintaining beams in collision
  - Intra-train feedback

Superconducting RF Module & Test Facility (SMTF) at Fermilab

Goal: Develop U.S. Capabilities in high gradient and high Q superconducting accelerating structure in support of the International Linear Collider, Proton Driver, RIA, 4th Generation Light Source and other accelerator projects of interest to U.S and the world physics community.



SMTF Collaboration

Collaborating Institutions and their representative

- Argonne National Laboratory: *Kwang-Je Kim*
- Brookhaven National Laboratory: *Ilan Ben-Zvi*
- Center of Advanced Technology, India: *Vinod Sahni*
- Cornell University: *Hasan Padamsee*
- DESY: *Deiter Trines*
- Fermi National Accelerator Laboratory: *Robert Kephart*
- INFN, Pisa : *Giorgio Belletini*
- INFN, Frascati: *Sergio Bertolucci*
- INFN, Milano: *Carlo Pagani*
- Illinois Institute of Technology: *Chris White*
- KEK: *Nobu Toge*
- Lawrence Berkeley National Laboratory: *John Byrd*
- Los Alamos National Laboratory: J. *Patrick Kelley*
- Massachusetts Institute of Technology: *Townsend Zwart*
- Michigan State University: *Terry Grimm*
- Northern Illinois University: *Court Bohn*
- Oak Ridge National Laboratory: *Stuart Henderson*
- Stanford Linear Accelerator Center: *Chris Adolphsen*
- Thomas Jefferson National Accelerator Facility: *Swapan Chattopadhaya*
- University of Pennsylvania: *Nigel Lockyer*
- University of Rochester: Adrian Melissions

Proposal is being prepared to be submitted to Fermilab by Feb. 18th 2005.

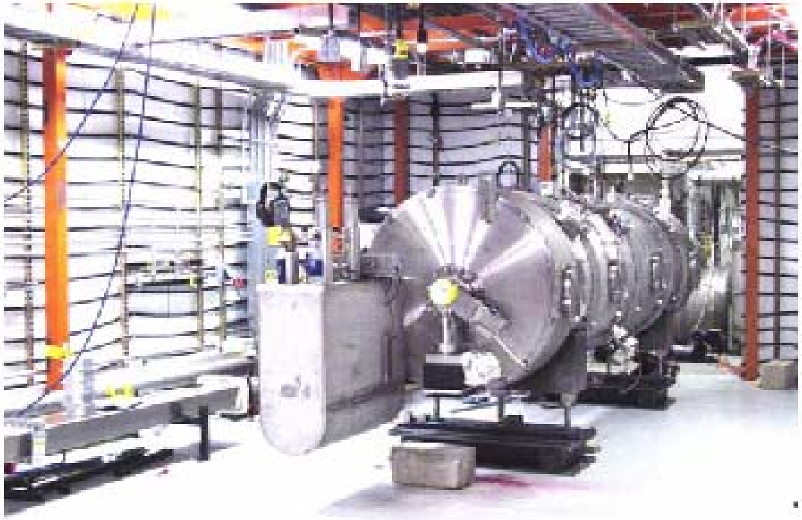
Perspective on SMTF

- Following the ITRP recommendation the first imperative is establishment of International capability in the fabrication of high gradient superconducting accelerating structures.
  - In USA we will be expanding upon existing scrf expertise at: Argonne, Cornell, Fermilab Jefferson Lab, MSU
  - Provisional goal is to have three U.S. and one European 1.3 GHz ILC cryomodules under test, with beam, by the end of 2009.
  - Build Front end and $\beta < 1$ part for the Proton Driver.

$\Rightarrow$ **Fermilab is committed to providing the US leadership with close coordination with the ILC-Americas collaboration.**

- Fermilab point of view: SMTF is the primary mechanism for providing this leadership while allowing us to simultaneously integrate our ILC and PD R&D activities.

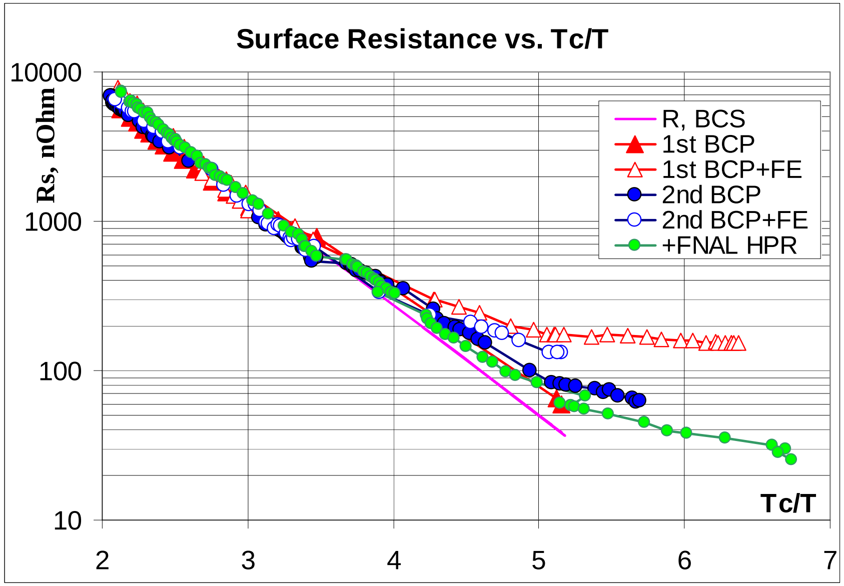
Jlab - Cryomodule Assembly and Test Areas



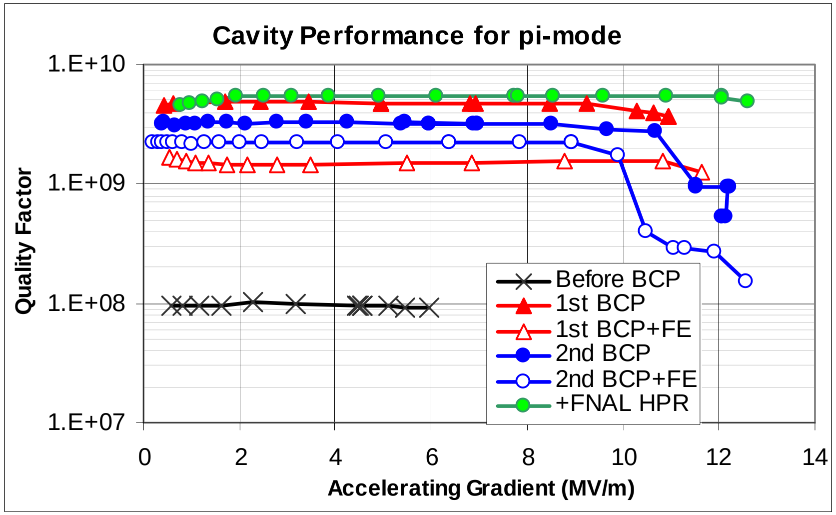
Cryomodule Test Facility (CMTF)


Cornell
Cavity
Test Pits

Cold Test of the 3-cell 3.9 GHz cavity in the Vertical Dewar



Q



Gradient Mv/m

<u>Test history</u>

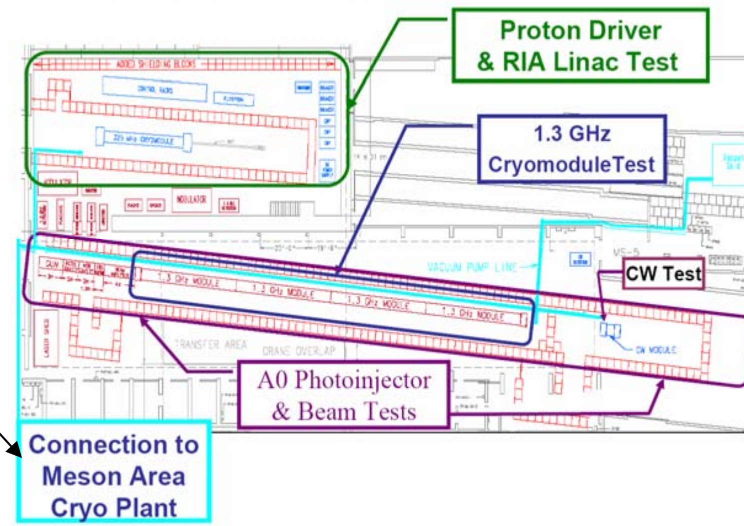
#1 – No BCP

#2-5 - After100 μm BCP, HT, HPR(15’) -JLAB

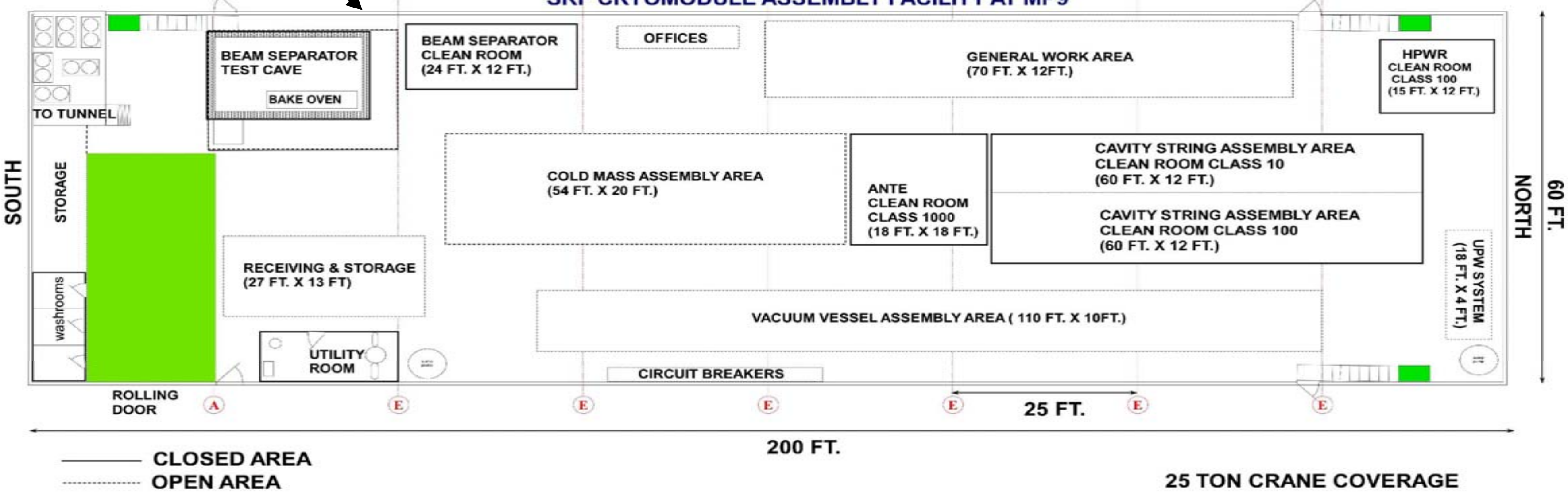
#6,7 – Additional 20 μm BCP, HPR(30’)-JLAB

Meson Area Fermilab

FNAL Meson Area SM&TF Layout Concept



SRF CRYOMODULE ASSEMBLY FACILITY AT MP9

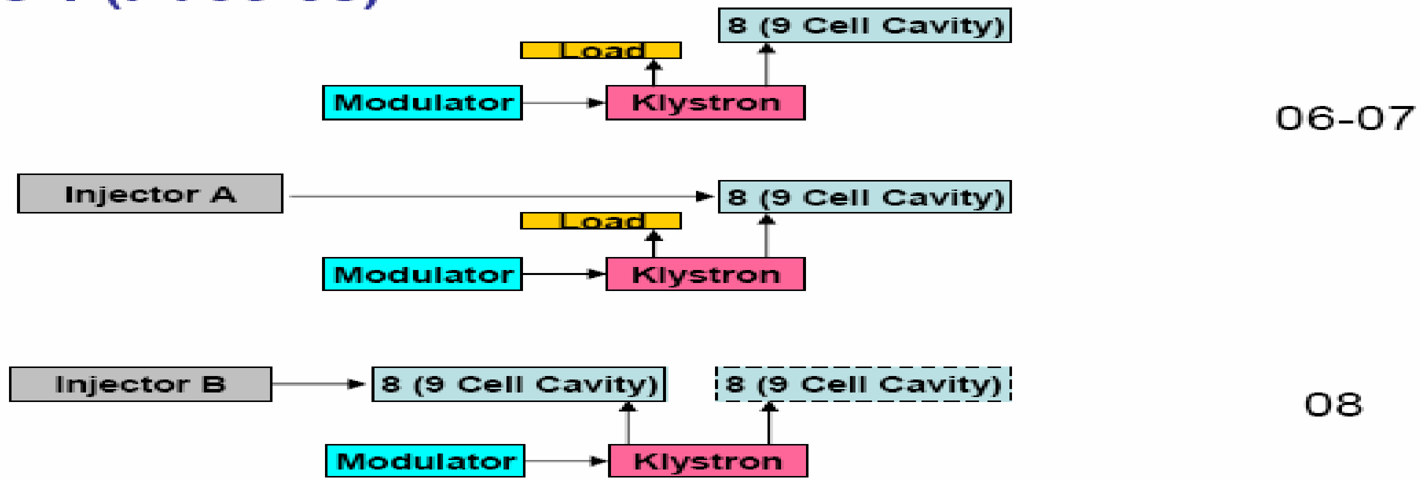


International Linear Collider

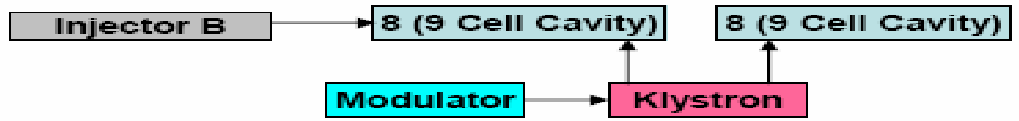
- Establish a high gradient, 1.3 GHz cryomodule test area at Fermilab with a high quality pulsed electron beam using an upgraded A0 photo-injector.
- Establish a prototype factory with infrastructure for the assembly of cryomodules using cavities produced at collaborating institutions and industries.
- Fabricate 1.3 GHz high gradient cryomodules in collaboration with laboratories, universities and U.S. industrial partners. Test cryomodules and other RF components as fabrication and operational experience is acquired and designs are optimized.
- Demonstrate 1.3 GHz cavity operation at 35 MV/m with beam currents up to 10 mA at a ½ % duty factor.
- Develop the capability to reliably fabricate high gradient and high-Q SCRF cavities in U.S. industry.

Phases of ILC Test Facility

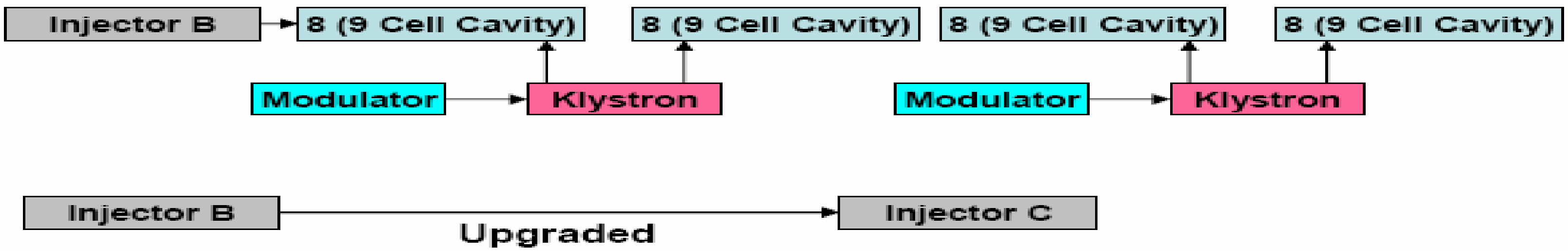
Phase 1 (FY06-08)



Phase 2 (08-09)



Phase 3 (FY09-...)

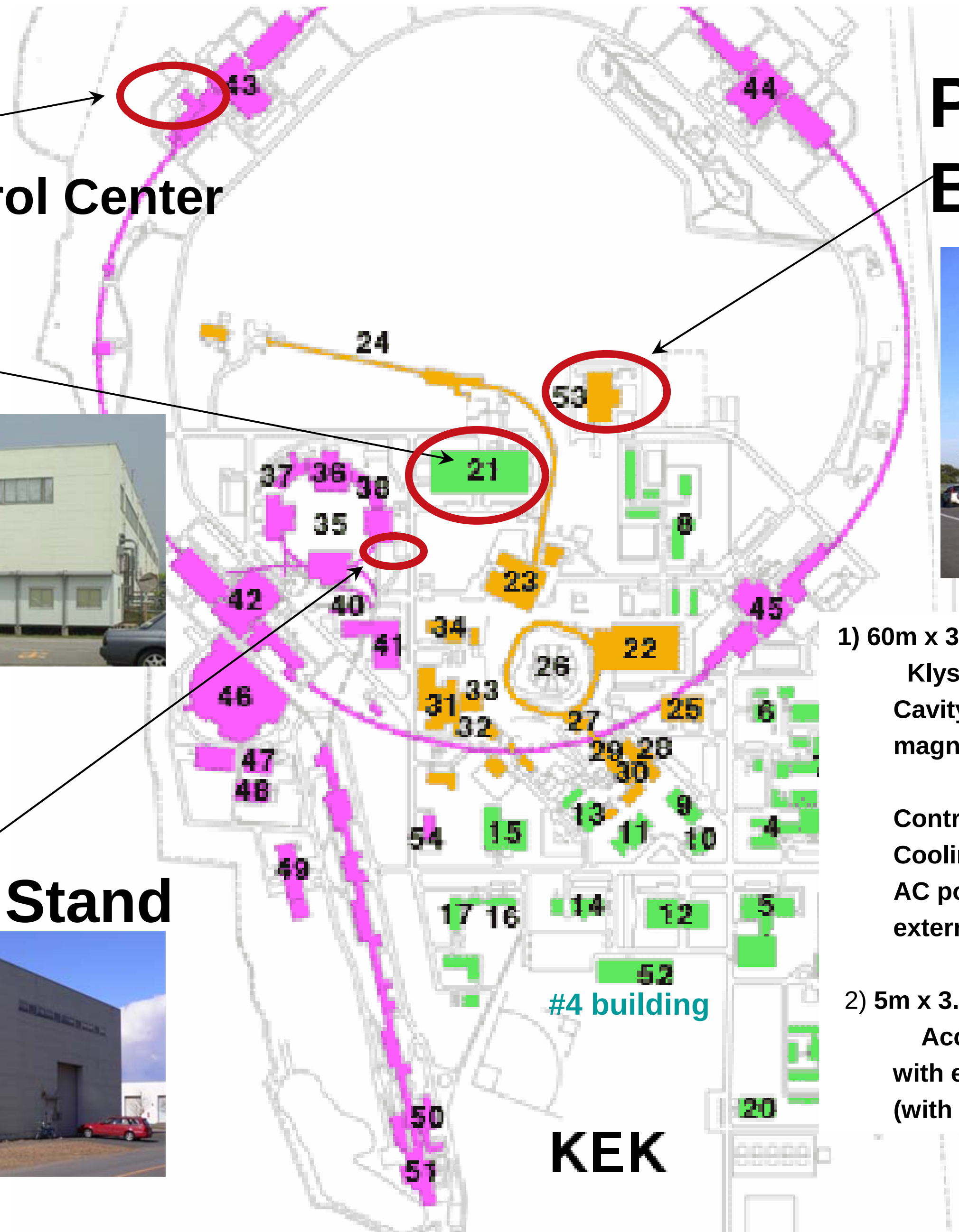


Location of Test Facilities

KEK-B
He Plant Control Center

ATF

L-band R&D Stand

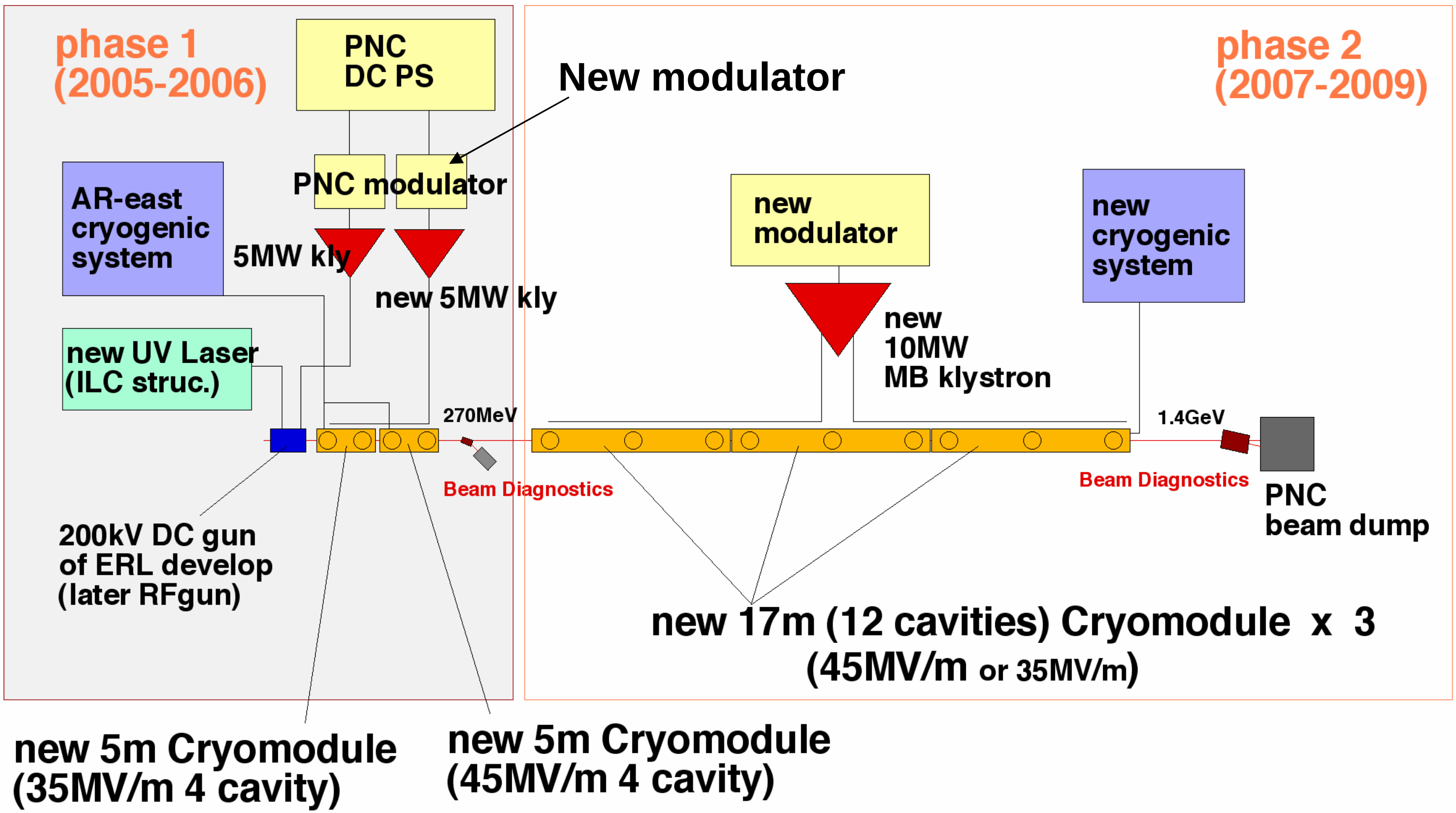


Proton Linac Building(STF)

1) 60m x 30m building:
   - Klystron Gallery (with extendable space)
   - Cavity installation room
   - magnet power supply room (with extendable space)
   - Control room (with extendable space)
   - Cooling water facility
   - AC power yard
   - external Tent House

2) 5m x 3.85m x 93.5m tunnel:
   - Access hatch only 2m x 4.5m with elevator (with extendable space)

Plan of Superconducting RF Test Facility (STF)



V1.1 Hitoshi Hayano, 12/08/2004

Technology Studies

- Determine the maximum operating gradient of each cavity & its limitations.
- Evaluate gradient spread and its operational implications.
- Measure dark currents, cryogenic load, dark current propagation, and radiation levels.
- Measure alignment of the quadrupole, cavities and BPM in-situ using conventional techniques (e.g. wire or optical).
- Measure vibration spectra of the cryomodule components, especially the quadrupole magnet.
- Measure system trip rates and recovery times to assess availability.
- Develop LLRF exception handling software to automate system and reduce downtime.
- Evaluate failures with long recovery times: vacuum, tuners, piezo controllers, and couplers.

Physics Measurements

- Beam energy: a spectrometer would provide an independent and accurate measurement of the accelerating gradient (rf based techniques are not as accurate).
- Long-range wake-field characterization: Measure frequency spectra of bunch positions downstream of cryomodule to search for high Q cavity dipole modes that could cause beam break-up in the ILC. Correlate these data with HOM power measurements.
- Tests of low-level rf system: demonstrate that a < 0.1% bunch-to-bunch energy spread can be achieved in a 1 msec bunch train.
- Impact of the SCRF cavity on transverse beam dynamics: measure the beam kicks caused by the fundamental mode fields.
- Study beam centering based on HOM dipole signals.

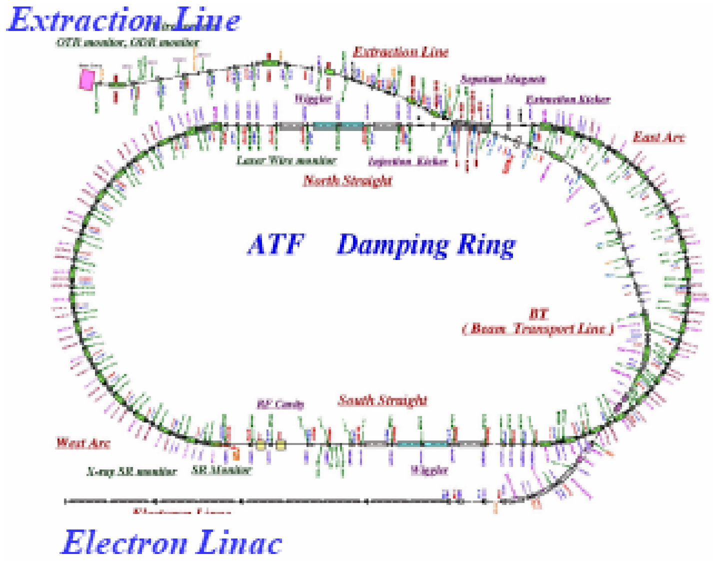
SMTF& STF: New Initiatives

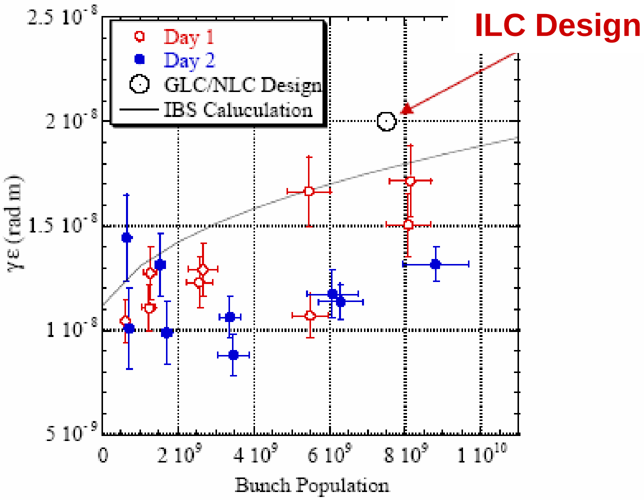
- Establish a superconducting radio-frequency (SRF) accelerator facility at Fermilab and KEK
  - Would provide the primary development and testing forum for major SRF-based projects in high energy physics
    - International Linear Collider
    - Fermilab Proton Driver,
    - Complement the existing and planned SRF facilities at other laboratories for nuclear physics and materials and life sciences.

- SMTF (Fermilab), TTF (DESY) and STF (KEK) are collaborating on these R&D.

ILC Technology Status
Damping Rings

- The required emittances, $\varepsilon_x/\varepsilon_y$ = 8.0/.02 μm, have been achieved in the ATF at KEK





- Performance is consistent with IBS, however,
  - Single bunch, e^-
  - Circumference = 138 m

ILC Technology Status

Damping Rings

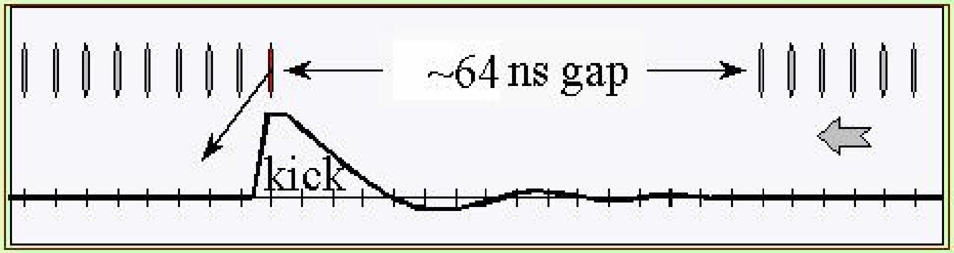
- The total length of the ILC beam pulse is:

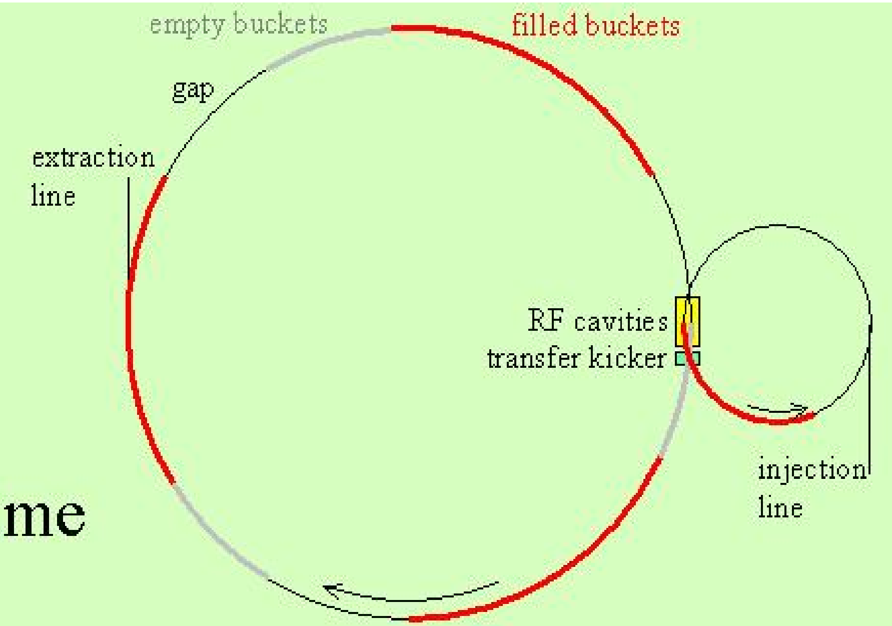
$$2820 \times 337 \text{ nsec} = 950\ \mu\text{sec} = 285 \text{ km (!)}$$

- This creates many unique challenges in the ILC damping ring design:
  - Multiplexing the beam ($\times$16 in the TELSA TDR)
    - Requires fast (~20 nsec rise/fall time kicker for single bunch extraction)
  - Circumference is still ~285/16 = 18 km
    - Space-charge is an issue because of the large C/ε_y (a first for an electron storage ring).
    - X/Y “transformer” used to mitigate.
- A number of ideas exist for reducing the circumference and associated challenges.

ILC: Small Damping Ring

Multi-Bunch Trains with inter-train gaps





- always inject and eject the last bunch in a train
- kicker rise time < 6 ns, but fall time can be ~gap length
- beam loading maintained by ~100 m ring with shared RF system
- ~6 km ring filled by transfers of undamped trains from the ~100 m ring

J. Rogers

Damping Ring

TESLA TDR Damping Ring 6.4.2

August 26, 2004

Lattice Parameters

Energy	E	5 GeV
Circumference	C	17 km
Revolution Frequency	f_0	17.634 kHz
RF Voltage	V_{RF}	50 MV
RF Frequency	f_{RF}	497.28 MHz
Harmonic Number	h	28200
Horizontal Tune	Q_x	76.310
Vertical Tune	Q_y	41.180
Synchrotron Tune	Q_s	0.0707
Momentum Compaction	α_p	1.22×10^{-4}
Natural Bunch Length	σ_z	6.04 mm
Natural Energy Spread	σ_δ	1.29×10^{-3}
Energy Loss per Turn	U_0	20.4 MeV
Horizontal Damping Time	τ_x	27.9 ms
Vertical Damping Time	τ_y	27.9 ms
Longitudinal Damping Time	τ_ϵ	13.9 ms
Natural Emittance	ϵ_0	0.508 nm
Horizontal Natural Chromaticity	ξ_x	-125
Vertical Natural Chromaticity	ξ_y	-62.5

Beam Parameters

Number of Bunches	n_b	2820
Bunch Spacing	$\Delta\tau_b$	20.1 ns
Particles per Bunch	N_0	2.0×10^{10}
Average Current	I	159 mA

ILC Small Damping Ring Version 0

August 26, 2004

Lattice Parameters

Energy	E	5.066 GeV
Circumference	C	6.114 km
Revolution Frequency	f_0	49.034 kHz
RF Voltage	V_{RF}	27.720 MV
RF Frequency	f_{RF}	500.00 MHz
Harmonic Number	h	10197
Horizontal Tune	Q_x	56.584
Vertical Tune	Q_y	41.618
Synchrotron Tune	Q_s	0.0348
Momentum Compaction	α_p	1.42×10^{-4}
Natural Bunch Length	σ_z	6.00 mm
Natural Energy Spread	σ_δ	1.51×10^{-3}
Energy Loss per Turn	U_0	7.73 MeV
Horizontal Damping Time	τ_x	26.7 ms
Vertical Damping Time	τ_y	26.7 ms
Longitudinal Damping Time	τ_ϵ	13.4 ms
Natural Emittance	ϵ_0	0.548 nm
Horizontal Natural Chromaticity	ξ_x	-74.4
Vertical Natural Chromaticity	ξ_y	-55.4

Beam Parameters

Number of Bunches	n_b	2820
Number of Bunch Trains		60
Bunches per Train		47
Bunch Spacing Within Train	$\Delta\tau_b$	6.0 ns
Spacing Between Trains		340 ns
Particles per Bunch	N_0	2.0×10^{10}
Average Current	I	443 mA

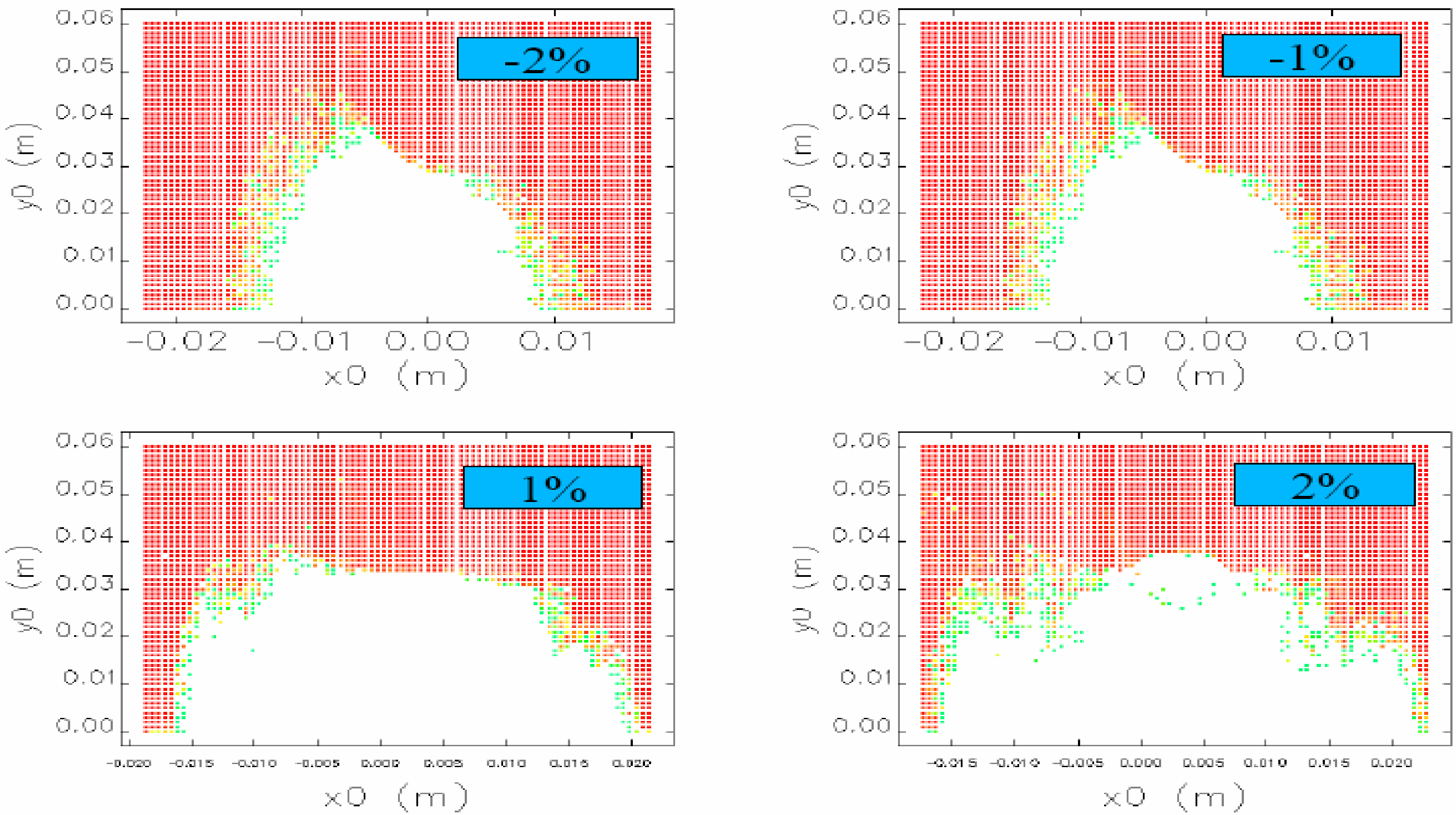
Aimin Xiao

Calculations for the 6-km Ring

- Dynamic aperture (DA) without errors
- DA for off-momentum
- Frequency map
- DA boundary with errors
  - Canonical wiggler, general magnet errors, orbit correction, tune correction, chromaticity correction.
  - 100 seeds to calculate the variation of dynamic aperture boundary
- These calculations are done using ANL code elegant. This code has been used for APS and its upgrade designs.

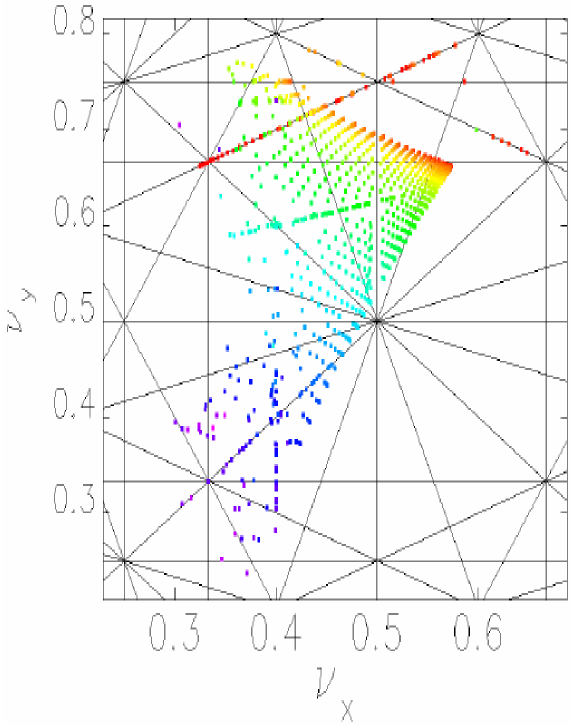
Damping Ring Collaboration with ANL

Off-Momentum Dynamic Aperture



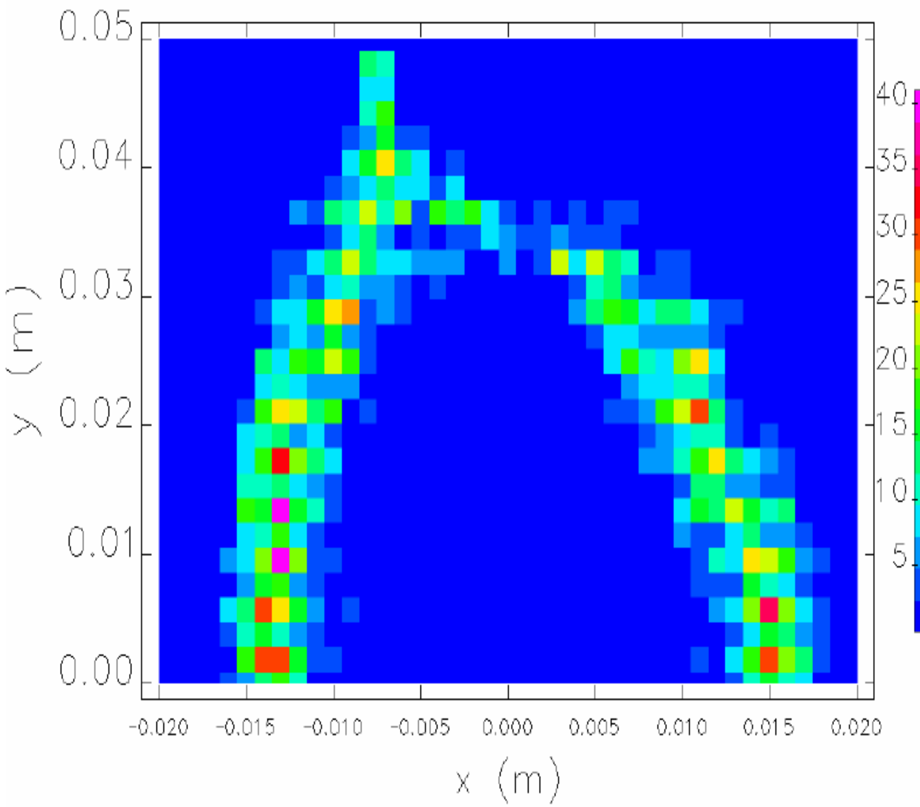
FNAL/ANL Damping Ring Simulation

Frequency Map Analysis



- 500-turn tracking, 20 kicks per element
- Color code shows change in tune
- 50 independent jobs, results collated with SDDS script
- Used ~50, 1.8 GHz CPUs simultaneously
- Took ~1 hour

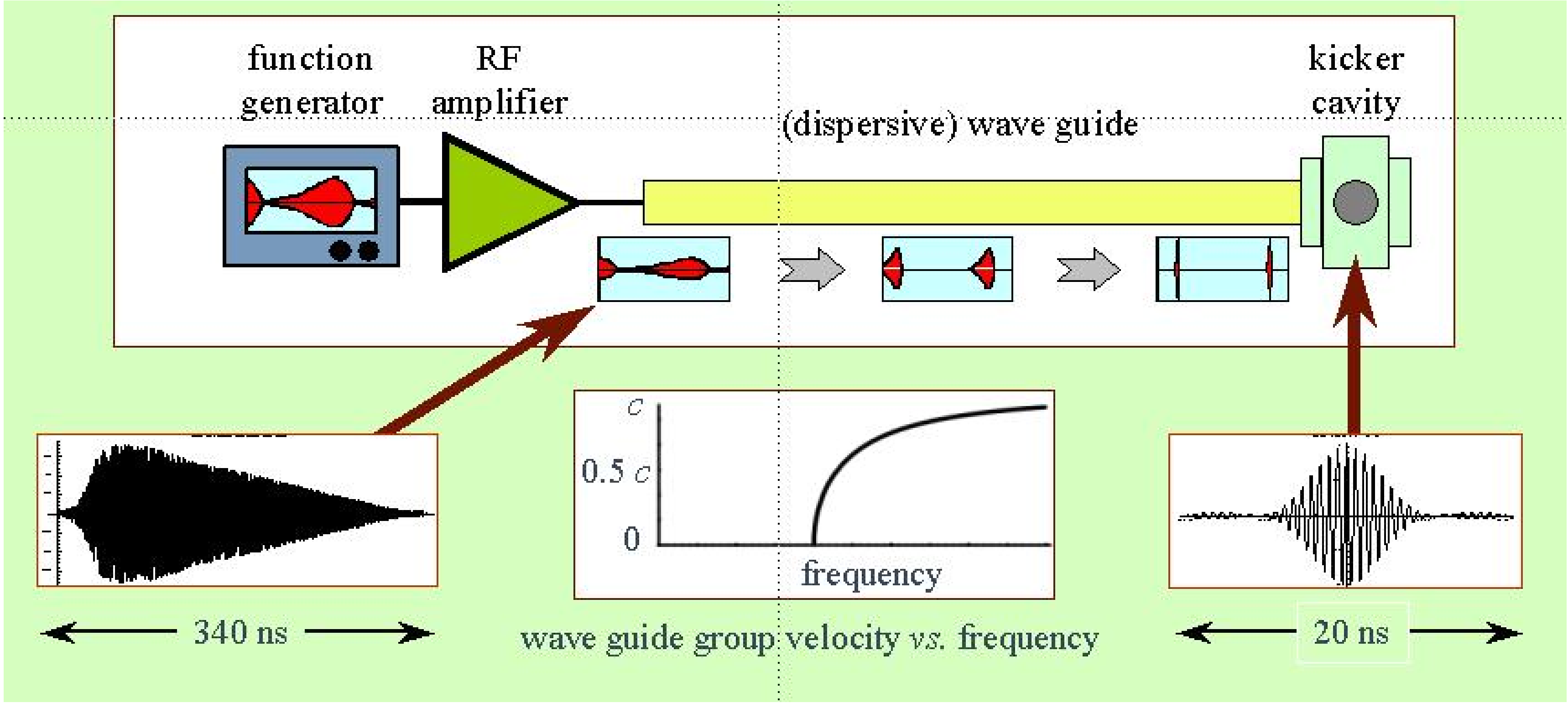
DR6km 100-Turn Dynamic Aperture



100 elegant runs with 100 seeds   ANL/FNAL Nov 2004

– These calculations have just started

A Pulse Compression Fourier series Kicker



This design is being developed by George Gollin in collaboration with Ralph Pasquinelli et al.

Damping Ring: Instabilities

RF and Beam Stability Issues (K.Y. Ng)

Single-Bunch			
Longitudinal	$\left.\frac{Z_0^{\parallel}}{n}\right\vert_{\text{eff}} \lesssim 150\ \text{m}\Omega$	safe	Tesla 100 mΩ
Transverse	$\left.Z_1^{V}\right\vert_{\text{eff}} \lesssim 2.34\ \text{M}\Omega/\text{m}$	safe with space charge	Tesla 1.8 MΩ/m
Multi-Bunch			
Longitudinal	$\tau \gtrsim 20$ ms $> \tau_{\text{damp}} = 13.5$ ms	safe	Tesla 134 ms
Transverse	$\tau^{-1} = 9600\ \text{s}^{-1}$ (5 turns)	safe with damper	Tesla 15300 s^{-1} (1.5 turns)
Electron Cloud			
w/o solenoids	$\tau \sim 3.3$ ms		
with solenoids	$\tau \sim 1$ s	safe	
Fast-Ion Instability			
preliminary simulations	emittance grows by $\sim e^{40}$, but $< 20\%$ with feed back		
RF			
12 sc cavities	syn. angle variation $< 0.09°$ (beam loading) half bunch length increase ~ 0.5 ps		

Fermilab Site Studies

- Near Surface Design
- Baseline Site Studies
- 1 Tunnel Vs. 2 Tunnel
- NIU/FNAL: Hydrological and Ground Motion
- Radiation Shielding Studies
- Tunnel Cross Section Development
- Cooling Pond Vs. Cooling Tower

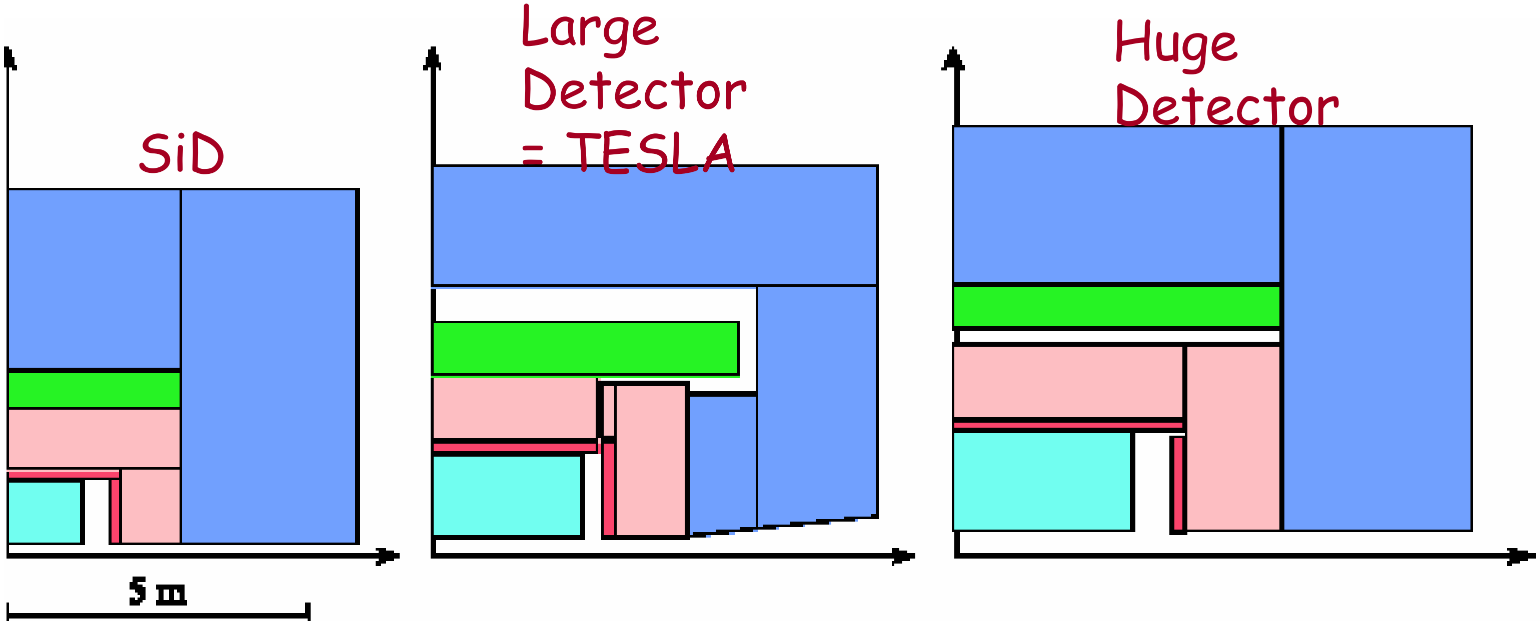
International Linear Collider
ILC America @ Fermilab

ILC detector concepts

Innovative names

For the moment three concepts have emerged (final meeting in Taiwan) and have been launched.

All detectors are BIG



All Si tracking; smaller; hopefully cheaper with same performance.
Centered in US (SLAC & FNAL + Users)
Leadership at FNAL& SLAC *(Jaros/Weerts).*
Had mtgs at Victoria & Durham

TPC based tracking + Si tracking
Centered in EU + some US
Just forming
Based on TESLA work = advantage

Similar to Large version, but Bigger.
Driven Asian interests mainly.
Official launch in Taipei

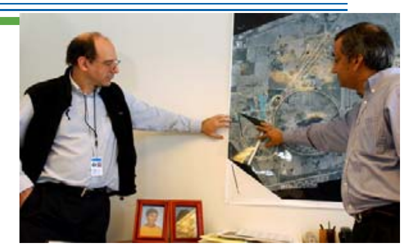
All global, but not easy.....

Fermilab and ILC communication

- Leads Interaction Collaboration
- Government outreach
  - Met 9/22 with state, federal legislative affairs reps
- Public Participation
  - Community Task Force
- Fermilab ILC Outreach Group
- Fermilab Today ILC Series
- Colloquia, Talks, Workshops

INTERACTIONS

Fermilab Community Task Force
On Public Participation



Fermilab Today

What's Up with the Linear Collider?

The Fermilab Long Range Plan:
Recommendations

- In support of this vision the FLRPC report offers a series of recommendations:
  - Linear Collider recommendations aim at establishing leadership in two significant technical areas (e.g. linac and sources), playing a leading role in the major engineering systems test, and taking the steps necessary to allow Fermilab to make a strong bid to become LC host laboratory.
    - Goal is to establish Fermilab as a leading contender for host lab.
  - Proton Driver recommendations aim at establishing the physics case, and developing the SC linac technology to the point that a cost benefit analysis can be done and the linac/synchrotron technology selection made.
    - Leading to documentation sufficient to support CD-0 (establishment of mission need in the DOE system).

Fermilab is pursuing linear collider and proton driver R&D in parallel.
The cold decision allows close alignment of these paths.

Fermilab: A Possible Host of ILC

A Truly International Laboratory will be necessary

Summary

- All regions of the world is involved in R&D
    - Fermilab/SLAC in USA
    - DESY in Europe
    - KEK in Asia
- After the Technology Recommendation ILC R&D effort is getting focused on SCRF Linac design.
- US laboratories and KEK have proposed SMTF and STF as cryomodule production and testing facility.
- There are considerable R&D challenges in the area of Source, Damping Ring, Machine and Detector Interface.
- ILC is by design a truly open and international collaboration.